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TECHNICAL MEMORANDUM CH2MHILL

Analysis of AMD Sludge Disposal in Hanna Stope

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1.0 Introduction

1.1 Purpose

This technical memorandum summarizes CH2M HILL's evaluation for disposal of acid mine drainage (AMD) sludge in the Hanna Stope of the Bunker Hill Mine. Sludge disposal is one of the remedy components that EPA and the State of Idaho Division of Environmental Quality (IDEQ) have identified as required for long-term mine water management at the Bunker Hill site. Evaluation of this disposal option was identified as a high-priority issue in the Presumptive Remedy Workshop No. 2 held March 2 and 3, 1999, in Spokane, Washington.

1.2 Project Background

A draft technical memorandum titled *Sludge Management—Bunker Hill Mine Water Presumptive Remedy* was prepared in January 1999 as part of the Bunker Hill Mine Water Presumptive Remedy Report. This memorandum was finalized in July 1999. As a result of that report and additional development of the Hanna Stope sludge disposal option, additional investigation and development of conceptual design was identified as a high priority issue.

Specifically, the area of the mine proposed for disposal of sludge is in the Hanna Stope located in the Milo Creek drainage basin as shown in Figure 1. The sludge is a byproduct from the treatment process of AMD that is continually being collected and treated from the underground areas of the mine. A location is needed to dispose of approximately 200,000 cubic yards of sludge (6,800 cubic yards annually for a period of 30 years).

This disposal option consists of transporting dewatered sludge from the treatment plant area to the Reed Landing at the entrance to the Russell Adit. At that location, the sludge would be transferred to a concrete-lined holding area until it was transferred into mine hauling vehicles. The mine vehicles would then transport the sludge along the Russell Adit on 5 Level to the cross-cut portals into the Hanna Stope, where it would be dumped and/or pushed into the prepared stope area.

The Presumptive Remedy report discussed the characteristics of the sludge, anticipated annual sludge volume and handling requirements, and presented the conceptual design and costs associated with preparing and transporting the sludge to the mine. This technical memorandum evaluates the concepts associated with storage at Reed Landing and transporting and depositing the sludge in the mine. Cost estimates are prepared which combine previously developed sludge drying and transportation costs with those determined from this technical memorandum, as necessary, for preparing the stope for sludge deposition and long-term operation and maintenance.

Disposal of sludge in the Hanna Stope would require plugging all openings leading away from the stope and/or placement of rock filter layers to prevent uncontrolled migration of sludge to other portions of the mine. Management of water that flows into the stope and water from the sludge would also be required to prevent:

- The buildup of excessive pressure on the sludge containment plugs (it may be possible to construct plugs that are capable of very high pressures, but additional site-specific information is needed to determine if this is feasible).
- Additional contamination of water that mixes with the sludge
- Mixing and dilution of the sludge which could lead to significant increases in the sludge volume for disposal
- Seepage and migration of sludge within the mine as a result of altered drainage paths

Two site visits were made during the initial Hanna Stope evaluation period to collect basic information regarding the configuration and size of the stope. Additional fieldwork was required as part of the current work in order to:

- Evaluate the geometry and interconnection of the drifts, laterals, shafts, and mine workings at the base and around the perimeter of the containment stope
- Develop a better understanding of the interconnections from the Hanna Stope to other parts of the mine
- Confirm potential locations and methods for plugging the lower portions of the stope for sludge containment
- Evaluate the method for plugging and the stress conditions under which the plugs must function
- Determine sources and approximate quantity of water flow into the stope
- Determine methods of potential control or diversion of influent water to keep the water out of the stope area
- Develop an approach for containment and removal of water that accumulates in the stope
- Determine access requirements and need for cleanup and rehabilitation of the Russell Adit as well as other passageways that might be necessary for development of the Hanna Stope as a waste disposal area for sludge
- Observe general condition of mine workings with regard to potential improvements for long-term operation and safety

An additional field reconnaissance trip was conducted on July 6, 1999. A technical memorandum re *Field Reconnaissance of Hanna Stope* is attached as Appendix A to this technical memorandum.

1.3 Project Scope

The scope of work for this technical memorandum includes the development of the conceptual design and cost estimate for sludge disposal in the Hanna Stope and identification of remaining unknown conditions and risks associated with implementation of this option.

As a result of the observations from these field trips, review of existing information, and discussion with others who are knowledgeable about the underground workings at the mine, several improvements have been deemed necessary in order to utilize the Hanna Stope for AMD sludge disposal. These improvements are described in detail throughout the rest of the text of this technical memorandum. A brief listing follows.

- Construct several new drifts at 6 Level to gain access to important workings in order to inspect and construct plugs at the strategic locations, restore access for mine drainage, and to maintain access to key areas for future monitoring of flows and water quality at 6 Level.
- Remove excess waste rock from the base of the stope to allow construction of filter layers in key areas along the west side of the stope.
- Import and construct filter layers in the stope using for safety reasons remotely controlled construction equipment, due to the hazardous working conditions created by overhead loose rock.
- Construct sand bed, collection piping manifolds, and sand cover in laterals and crosscuts adjacent to the east side of the stope.
- Construct concrete plugs at key locations to contain the sludge in the stope.
- Perform a safety inspection of all passageways where access will be required, note all areas to be repaired, and make repairs.
- Remove overburden and restore access past a cave-in near the Russell Portal.
- Shore and support access through a second cave-in located in the Russell Adit near the downramp to 6 Level.
- Improve access to the dump areas of the stope at 5 Level by constructing "turn-arounds" at all dump points.
- Install lights in the stope and at key locations at 5 Level.
- Install an air circulation system with air doors at strategic locations to manage air quality for use of diesel powered equipment to haul in the sludge.
- Construct diversion points and install sumps and pumps at 5 Level and 2 Level to control mine drainage water (additional reconnaissance would be needed to determine if gravity flow is feasible).

- Install pipes to divert groundwater away from the stope.
- Construct diversions at cross-cuts to prevent water from entering into the stope.
- Construct a holding basin to hold the sludge near the portal until it is transported into the mine for disposal.

1.4 Objectives

The objectives of this memorandum are as follows:

- Describe the known conditions of the drifts and laterals and stope for disposal of sludge.
- Identify design parameters for the key components of upgrades required for the Hanna Stope.
- Develop a conceptual design for disposal of sludge in the Hanna Stope.
- Prepare order-of-magnitude costs for the Hanna Stope disposal option (accuracy in the range of plus 50 to minus 30 percent).
- Conduct a preliminary evaluation of the implementability, effectiveness, and risks associated with this option.

1.5 Document Organization

This document is organized into the following sections:

Section 1: Introduction—This section includes the purpose, background information and scope of work, objectives, and document organization.

Section 2: Preparation of Base of Stope to Contain Sludge—This section presents the significant design parameters, criteria, and issues that will be used as a basis to prepare the stope for disposal of sludge and to construct plugs and filters necessary to contain the sludge and drain water from within the stope.

Section 3: Groundwater Control and Drainage—This section presents the significant parameters, criteria, and issues that will be the basis for design for control of groundwater away from the stope.

Section 4: Improved Access to Stope and Safety Issues—This section presents the issues and design basis for improvements that are considered necessary for improved access and safety.

Section 5: Evaluation of Hanna Stope Sludge Disposal Option—This section presents an evaluation of the implementability and effectiveness of sludge disposal in the Hanna Stope.

Section 6: Cost Estimate—This section presents an order-of-magnitude cost estimate for construction of the stope modifications developed in previous sections of the technical memorandum, and combines those costs with long-term operations costs, as well as with sludge drying and transportation costs for sludge disposal.

Appendix A—July 6, 1999 field reconnaissance trip memorandum.

Appendix B—Cost estimate details.

2.0 Preparation of Base of Stope to Contain Sludge

This section identifies key design components for sludge containment and water removal at the base of the Hanna Stope.

2.1 Description of the Problem

The base of the stope (6 Level) has many cross-cuts, laterals, and several raises and other mine workings in the perimeter area surrounding the Hanna Stope. In addition, diamond drill holes and other exploratory work have further interconnected the workings to form a complex pattern of underground interconnections and passageways. Groundwater seepage currently migrates along some of these interconnections and passageways. In order to use the Hanna Stope for disposal of waste sludge, the drifts, raises, and other passageways leading toward and away from the stope must be plugged within the sludge storage zone (Level 5 down to Level 6), or provided with filter layers of rock and sand to prevent the release and migration of sludge into other parts of the mine.

Groundwater flows that can be observed in various drifts and raises surrounding the stope at the present time provides our greatest clues about how these passageways might be interconnected with each other and with the stope. Field inspections show that the mine drainage is currently being diverted along paths that avoid the Hanna Stope. Consequently, a relatively small amount of water is currently noted to be flowing out of the base of the stope through the various cross-cuts and raises leading from the stope. However, just because these passageways are presently dry or are known to transport only minimal groundwater flows is no assurance of the lack of other interconnections. Higher groundwater levels, such as would result from deposition of sludge in the stope, may very well reveal interconnections that were not previously known to exist.

As discussed in the site reconnaissance of the stope, and shown in Figures 2 through 8 of Appendix A, the conditions of the stope are well known along its east side. However, access to the west side of the stope is presently not possible. Our knowledge of the west side is based on existing maps of the old mine workings and our observations, monitoring, and understanding of groundwater flows at nearby points where it can be observed. For example, certain interconnections with the stope, nearby drifts, and raises are presently known to exist based on knowledge of where the water is currently flowing.

Development of sludge disposal in Hanna Stope is premised on the requirement that the present mine water flow regime not be altered or degraded as a result of this disposal option.

It is considered critically important to maintain the ability to control present and future groundwater flows within the underground areas of the mine. If sludge were to inadvertently escape from the disposal area into the surrounding passageways, then these drainages could:

- Become clogged with a release of sludge causing groundwater to divert into other channels, flooding, and a possible buildup of water in the stope or other areas of the mine. Water that collects in the stope could potentially dissolve sludge and eventually lead to decreased water quality.

- Cause a slow long-term migration of the silty sludge fines for long distances into the other parts of the mine, causing significant impact in terms of increased maintenance and removal in order to maintain control of the mine drainage.

Because of these concerns, development of the sludge storage option for Hanna Stope should be pursued as a viable option only under the condition that the risk of loss of sludge to other parts of the mine is demonstrated to be extremely low. In order to accomplish a high level of assurance that the sludge can be adequately contained, the preparation of the base of the stope, monitoring of mine drainage water, and performance testing of the stope are considered to be necessary. These concepts are discussed in more detail in the following sections.

2.2 Estimated Volume Available for Sludge Disposal

Measurements were taken during the site reconnaissance trip to determine the approximate volume available for storage of sludge in Hanna Stope (refer to Appendix A). The sludge can most easily be transported to the stope via the Russell Adit at the 5 Level. In the vicinity of the stope at 5 Level, several access points would likely be required in order to distribute the sludge across the entire base of the stope at 6 Level. Assuming that the stope would be filled entirely between 6 Level and 5 Level, the total available volume is estimated to be about 260,000 cubic yards. This assumes an average width of the stope of about 70 feet and a length of 600 feet. The height of the stope between 6 Level and 5 Level was estimated to be about 170 feet.

The base of the stope at 6 Level contains a substantial amount of waste rock that was left from previous mining operations. Since that time, additional rock debris has accumulated in the base of the stope, having fallen from the top and sidewalls. For the purposes of this conceptual design, it is assumed that a portion of this waste rock would remain in the base of the stope. Its total volume was estimated based on an average width of about 70 feet, a height of 30 feet and a length of 600 feet. Using these assumptions, the volume of waste rock is estimated to be about 30,000 cubic yards. As described in Section 2.5, approximately 13,000 cubic yards is estimated for removal. Therefore, the total volume available for sludge disposal in the stope is estimated at about 243,000 cubic yards. This volume is slightly greater than the 200,000 cubic yards of sludge estimated to be produced in a 30-year period.

Because of the uncertainty associated with the inability to verify that all the interconnections are plugged, a sand/rock filter layer is recommended to control the migration of sludge from the stope. The available volume for sludge disposal must be appropriately reduced to account for the placement of these filter materials. The use of filter layers within the stope is discussed subsequently in this technical memorandum. An estimated 10,000 cubic yards of additional material will be required to construct the filter layers, with a corresponding loss in available volume for sludge disposal.

2.3 Design Parameters/Issues

As previously discussed, it is important to prevent the migration of silty sludge fines into other areas of the mine. The surest way to accomplish this goal is to construct a concrete plug at all passages that lead out of the stope. Our understanding of the workings on the east side of the stope is good. However, we do not have access to the west side of the stope, and we cannot be certain that the stope is not connected to the Williams Raise at the northwest end. We believe that the stope is in fact connected to the Hall Raise, and this connection must somehow be plugged with concrete if the stope is to be sealed off from the lower levels. There is presently no access to the area to view the opening. In addition, mine maps suggest that portions of the East Becker and McGatlin Drifts may intersect portions of the base of the Hanna Stope, south of the Hall Raise. We are not presently aware of other interconnections on the west side of the stope; however, the workings are complex. The possibility exists that other connections are present that we are unaware of.

A second method of containing the sludge would be to provide a sand/rock filter to contain it. Such a filter must be designed to control the sludge from migration when subjected to significant hydraulic pressure gradients, such as would exist when the elevation of the sludge and water in the stope begins to build. In order to achieve the gradation requirements, a filter of this type must consist of at least three separate filter layers to transition between the coarse base rock and the fine sludge material to be stored in the stope.

The sludge is non-plastic or exhibits only low plasticity, and is therefore subject to piping or migration along voids or seepage paths in the waste rock at the base of the stope, especially when subjected to high pressure gradients. To control this condition, a properly sized and graded filter is required, using successively finer aggregates from the bottom up to the level that would be in contact with the waste sludge. It is important that no holes or voids be present in the various filter layers, or else the sludge will short-circuit through such holes, causing piping, loss of sludge, and failure of the filter material. The filter layers would be sized or graded so that each layer would control the movement or migration of the successively finer layers to be constructed above that layer. In order to control risk of a blow-out and the piping and loss of sludge that would result, all potential seepage channels and voids in the rock must be covered by each of the filter layers described.

2.4 Construction of Concrete Plugs

This section describes the conceptual design of plugs to contain the sludge in the stope. Other plug designs are possible. Design options should be considered when site-specific information is available.

It is assumed that concrete plugs will be required at selected locations in the cross-cuts and laterals leading from the base of the stope. The known locations where plugs are required are shown in Figure 2. The rock at each plug location should be scaled to remove any loose rock, and the base of the drift at each plug location should be pressure-washed, as required, to expose clean fresh rock surfaces. The length of the plugs should be about twice the diameter of the drift and should completely seal off the drift.

Drainage should be provided through the plugs where appropriate. Figure 2 illustrates how drainage pipes can be constructed to achieve the required drainage from the upstream side of the plugs, and Figure 3 illustrates the construction procedures for installation of drainage collection provisions along the upstream sides of the plugs using a manifold of perforated piping and sand backfill.

In order to install plugs on the west side of the stope, safe access will be required. This will require driving a new drift around the northwest end of the stope, as shown in Figure 2. The new drift should tie into the existing East Becker Drift and should allow access to the Williams Raise at a safe distance away from the walls of the stope. The new drift should continue parallel to the west side of the stope, extending to the Hall Raise or beyond (refer to the memorandum and figures in Appendix A from the reconnaissance report for plans and sections of the likely positions and arrangement of existing drifts and raises).

If other connections to the stope are found to exist at the northwest end, then the existing mine drainage from the Williams Raise should be diverted by construction of a new inclined raise or ramp located farther away from the stope. The new raise should reconnect the existing East Becker Drift to 5 Level or to the Williams Raise at a safe distance above the interconnections to the stope if such connections exist. All other passageways, drill holes, and connections that are found should also be plugged. After the water has been diverted into the new raise, the Williams Raise and a section of the East Becker Drift (located downstream from the new parallel drift) should be permanently sealed with concrete plugs.

Little is known about the Hall Raise. It is believed that the raise opens into the base of the stope or near the west edge of the stope at 6 Level (see figures in Appendix A). This raise will need to be plugged. If the opening is small (less than about 5 feet), the passageway could be sealed by construction of a concrete plug over the entry to the raise. The opening would have to be located and observed before this concept could be considered further. The concrete would have to be placed against cleaned, fresh undisturbed rock surfaces and placed to completely seal the raise from the stope. The concrete would have to be designed to account for the sludge and water pressure that would exist in the stope when filled with sludge.

Although not known for certain, it is believed that the Hall Raise opens directly into the base of the Hanna Stope. If this is true, then safety becomes an important consideration, and access to the Hall Raise opening may be impossible to achieve during the base preparation for placement of a concrete seal. Because of this concern, the option of sealing the raise in the base of the open stope is dropped from further consideration in favor of an option that allows better access to the raise for purposes of plugging.

A more predictable concept that can be utilized to plug the Hall Raise would require driving a new drift along the west side of the stope to the location of the Hall Raise. The new drift should be located a safe distance away from and below the floor elevation of the stope. Once the Hall Raise is located, exposed, and inspected, the raise should then be permanently plugged and sealed with concrete. This concept avoids the safety issues associated with access into the stope and provides a controlled structural solution for accommodating the hydraulic pressure of the sludge and water in the stope. This plugging concept is shown in Figure 2; a cross-section of the stope illustrating this plugging concept is also shown in Figure 4.

A monitoring program should be established to carefully document the flows, seasonal variation, and water quality in all of the laterals, drifts, and raises near the Hanna Stope. All baseline conditions should be well established prior to placing sludge in the stope. Turbidity levels and existing muck levels in the drifts should be noted and monitored for all locations prior to placing sludge in the stope. Once disposal of sludge begins, the monitoring should be geared for early detection of potential escapement of water and sludge from the stope. If detected, additional areas may have to be sealed to prevent further migration of sludge into the mine.

2.5 Removal of Waste Rock and Construction of Filter Layers in Base of Stope

Because of the uncertainty associated with the workings along the west side of the stope and possible connection to passageways leading to other parts of the mine, a rock filter blanket should be constructed in the areas considered to have possible interconnection. Such is the case along about 400 feet of the southwestern portion of the stope at 6 Level, where the East Becker and/or McGatlin Drifts may intersect the base of the stope. To construct filter layers as described previously, a portion of the waste rock in the base of the stope should be removed and disposed of. The quantity of waste rock to be removed has been estimated to total about 13,000 cubic yards. A portion of the waste rock would be left in the base of the stope, graded into about a 4:1 slope, and stacked up against the west hanging wall of the stope. This configuration is shown in Figure 3. It is assumed that the waste removal and regrading would occur in the entire 400-foot-long section of the southwest side of the stope.

This work would be accomplished using remotely controlled earthmoving equipment (it is assumed that it would be unsafe to allow manned entry into the stope for this purpose due to the hazard of rockfall from above). A remote observation point(s) would be prepared and lighting installed in the stope where the earthmoving equipment could be observed. This work would require drilling and blasting of some of the large rock blocks that have dropped into the base of the stope before they could be moved.

The filter should then be constructed over the top of the regraded waste rock as shown in Figure 3. The filter layers would be sized or graded so that each layer would control the movement or migration of the successively finer layers to be constructed above that layer. In order to control risk of a blow-out and the piping and loss of sludge that would result, all potential seepage channels and voids in the rock must be covered by each of the filter layers described. In order to construct such a filter, imported materials of the proper gradation would be necessary. This concept requires construction of such a filter over all potential openings and passages leading from the stope and would be used over the same 400 foot length of regraded waste rock at the southeast end of the stope, as previously described.

To construct the filter, multiple layers of successively finer materials would need to be placed over the regraded base of waste rock. The first filter layer should be sized to avoid migration of the filter rock into the voids of the waste rock and into mine openings that could exist in the stope. It is assumed that the first layer of filter rock would require a rock mixture ranging in size from about 2 feet down to about 4 inches. The thickness of this layer should be about 4 feet. The next filter layer (intermediate layer) would require a finer rock gradation, estimated to be from about 6 inches down to about 1/4-inch in size. The third and final filter layer would require use of a clean sand. This could be concrete sand meeting the requirements of ASTM C-33 or could likely utilize waste slag, which appears to be of the proper gradation for this filter material. Waste slag is readily available at the Central Impoundment Area (CIA) waste pile and should provide an adequate filter to prevent migration of the silty sludge through the filter layers. The thickness of the intermediate filter layer and the sand filter layer should each be about 3 feet. This adds up to a total filter layer thickness of about 10 feet when completed, not counting the thickness of the redistributed waste rock.

2.6 Construction of Water Collection System in Laterals and Cross-Cuts

A water collection system should be installed at each plug location. The water collection should consist of non-perforated high density polyethylene (HDPE) pipes through the plugs. The pipe should be connected to a slotted HDPE piping manifold to be installed in the bottom of the parallel drifts and cross-cuts, inside the sludge storage area.

Sand bedding consisting of clean concrete sand or waste slag (meeting ASTM C-33) should first be placed in the base of the drifts and cross-cuts along both the east and west sides of the stope, for the full length of the stope. This sand should meet filtering criteria for contact with the sludge. The sand should be initially constructed to a depth of about 1 to 2 feet, as required to bed the pipe away from the rock surfaces in the floor of the laterals and cross-cuts, then the perforated HDPE piping should be installed on the sand bedding and additional sand cover should be added. The total depth of sand cover should be a minimum of about 2 feet over the top of the pipe manifolds when completed. Clean-out access into the manifolds should be provided where possible. Figures 2 and 3 show the conceptual configuration of the concrete plugs and the manifold piping system in plan and section, respectively.

3.0 Groundwater Control and Drainage

3.1 Description of the Problem

As discussed previously, it is believed that only a relatively small quantity of mine drainage water currently flows directly into the stope from the surrounding areas. This is beneficial and should be maintained and improved where possible to keep water from draining into the stope. Maintaining the existing groundwater flows away from the stope can be expected to provide:

- Improved water quality by not allowing the groundwater to come in contact with the waste sludge
- Help control the hydraulic head acting on the sludge
- Should help achieve greater storage volume in the stope by attaining a lower water content of the waste sludge in the stope

The existing groundwater flows are illustrated in the figures presented in the reconnaissance report that is attached as Appendix A to this technical memorandum.

3.2 Design Elements

Improved drainage and installation of sump pumps will be required at selected locations in order to better control and route the groundwater in areas surrounding the stope. The necessary improvements should consist of improved gravity drainage channels along the drifts where necessary to control the flow to existing discharge points. The base of the drifts should be mucked out in several areas to provide improved drainage. Small concrete dams should be provided at access points to the stope to divert water away from the stope. Sumps should be created, and pumps and piping should be installed to collect water and pipe it to the desired discharge locations. Electrical service will be required at each of the pump locations.

Sumps should be provided along the various drifts at selected locations on 2 Level, the various sublevels below 2 Level, and along 5 Level. Most of the sump locations will be required on 5 Level where a significant portion of the total flow is currently diverted by gravity flow along the east side of the stope. Most of the groundwater at this level originates from the New and Old East Reed Drifts and from drainage that passes down the waste pass from 2 Level. Pumps and plastic piping should be installed to collect and divert most of this water to the Williams Raise where it currently drops to 6 Level outside the northwest end of the stope. Figures 5 and 6 show the proposed sump locations, piping runs, and discharge points at 2 Level and 5 Level, respectively.

Groundwater also enters the mine along the Russell Adit. Most of this water drains to the southeast toward the stope, then is diverted west to the Williams Raise. Collection and improved channel drainage along this section will help dry up the base of the drift and should help control the maintenance of the drift for the sludge haul vehicles.

Groundwater also enters the ramp that leads from 5 Level down to 6 Level. Water that collects in this drift currently drains to a point near the southeast end of the stope, slightly above 6 Level. There it is diverted into a raise that drops into the Bunker Hill No. 6 Lateral. The water then flows along the east side of the stope toward the northwest along this lateral. This drainage must be maintained. A concrete plug will be required near the end of the ramp adjacent to the stope, downstream from the drainage connection to Bunker Hill No. 6. A new ramp should be driven to provide monitoring and maintenance access from the 5 Level ramp down to the Bunker Hill No. 6 Lateral at a point a safe distance away from the concrete plugs shown in Figure 2.

4.0 Improved Access to Stope and Safety Issues

4.1 Description of the Problem

Improved access will be required for construction equipment and sludge hauling vehicles into the mine. Two cave-ins have occurred along the Russell Adit, which will have to be opened. Additional areas of poor rock quality will require the installation of rock bolts and steel mats. Construction of improved maneuvering areas near each of the stope dump points will be required, and several new drives are necessary to open up areas along the west side of the stope and to provide future access to monitoring points along 6 Level. All passageways should be carefully inspected, and all loose rock should be barred from the sides and roof of the drifts. New rock bolts will be required at selected locations for improved stability.

A secondary access route along 2 Level and the service raise should be inspected and improved, as required, to provide safe access in and out of the mine. A ventilation system and air doors will be required to provide adequate circulation of fresh air into the mine because diesel equipment will be operating in the mine.

4.2 Design Elements

4.2.1 Russell Adit Improvements

Concrete retaining walls and roof have been constructed along the first approximately 130 feet of the portal entry to the Russell Adit. The adit is about 9 feet wide along this section and will limit the size of the hauling vehicles to be used in the mine. At a distance of about 130 feet into the portal adit, the existing concrete support wall on the west side of the adit has failed and should be replaced.

The first cave-in is located about 150 feet into the adit. The cave-in has resulted from poor quality ground near the portal and will require excavation and removal of the overburden soil and rock in order to restore access. It is estimated that this cave-in zone is less than 150 feet in length.

Restoration of the portal will require excavation from the ground surface and will require the removal of about 20,000 cubic yards of soil and rock overburden material. It is assumed that this excavated material can be permanently placed as fill on nearby benches along the Reed Landing. New concrete walls and roof should be constructed, extending from the existing concrete-supported portal to beyond the first cave-in area. Beyond this point, the adit will probably need to be supported in areas with timber supports, beams, and lagging as required to support the walls of the adit in zones of poor-quality rock.

A second cave-in is located at a fault zone about 100 feet from the ramp leading from 5 Level down to 6 Level. The fault has resulted in poor quality rock along the fracture zone and along subparallel fracture zones for a width of several hundred feet along the adit.

It is assumed that this cave-in area will be reopened by installing new timber supports and blocking to fully support the sides and roof of the adit through this zone. Additional rock bolts and steel support matting should be anticipated in this section of the adit where poor rock quality was observed.

4.2.2 New Drifts and Improvement of Existing Drifts

New drifts will be required to provide construction access to the Williams Raise and the Hall Raise around the northwest end of the stope. Exploratory bore holes will be required at selected locations to help locate the stope and associated workings. A new drive will be required to connect the ramp from 5 level to the Bunker Hill No. 6 lateral for construction of plugs and drainage systems near the base of the stope, and for access for future monitoring.

Several of the existing laterals and drifts will likely need to be mucked out in order to gain improved access for regular monitoring and observation of mine drainage. Several of these existing laterals are known to contain areas with deep accumulations of muck and standing water. Pumps may be required at some locations in order to maintain access along these passageways. These areas include the Bunker Hill No. 6 Lateral, the East Becker Drift, the cross-cuts between the plug locations and Bunker Hill No. 6, and other drifts, especially at 6 Level surrounding the perimeter of the stope.

4.2.3 Additional Safety Requirements

Air doors will be required near the entry to the drift near the Reed Landing, at Asher Drift and East Reed Drift, and the Russell Portal. Air circulation system requirements will need to be determined on the basis of equipment type and duration for construction and operation conditions within the mine. The system will be required to supply airflow throughout the working and secondary exits from the mine. Currently it is anticipated that single air doors will be required at the Asher and East Reed Drift entrances, and a double air door at the Russell Portal. The double air door would be air (pneumatically) operated for equipment access to the mine.

All the applicable mine passages will need to be barred and scaled to remove loose rock material. Bolts, and in some locations mats, will be required to support the walls and roof of the drifts. New timber supports will be required in some areas to meet safety considerations.

Improved maneuverability will be required for the sludge hauling vehicles in the vicinity of the stope. Turn-around areas should be provided, and dump ramps and safety stops will be required in each of the cross-cut portals into the stope where sludge is to be dumped.

Lighting will be required in selected areas of the mine. The stope should be well lighted to provide good visual observation of the interior of the stope. The cross-cuts, turn-around areas and laterals surrounding the stope should be lighted to facilitate the maneuvering and placement of sludge. Areas that require frequent monitoring and maintenance (such as sump areas) should also be lighted.

5.0 Evaluation of Hanna Stope Sludge Disposal Option

The technical implementability and effectiveness of sludge disposal in the Hanna Stope is discussed below. Other considerations which are not evaluated are the economic impact to the remaining underground mining resource, and the impact to the site roads and the Reed Landing area where sludge would be staged prior to transport into the stope. These considerations need to be evaluated with the mine owner if this sludge disposal option is considered further.

5.1 Technical Implementability

The implementability of this option depends on the ability to plug all of the potential passageways that lead from the stope. If these passageways are not plugged and sealed, the sludge could pipe and erode into other areas of the mine where continued control of the mine drainage is essential. The conditions on the east side of the stope are reasonably well known where access is good. However, little is known about the existing conditions on the west side of the stope. Implementing this option requires that new drifts be driven to several of the known raises and drifts so that they could be adequately plugged. This option should also require that a portion of the waste rock in the base of the stope be removed and a multi-layered filter be constructed to provide an added degree of assurance against uncontrolled piping failure and loss of sludge into other areas of mine. Because of safety concerns, it is assumed that access into the stope is severely limited and work that is performed in the stope would be by remotely controlled construction equipment.

Even if the known passageways are plugged and a filter is constructed to control piping and loss of sludge from the stope, there is still a risk that other passages may exist that cannot be detected by the means proposed. Therefore it is recommended that the stope be filled (at least partially) with water to perform a leakage test. Baseline flows and water quality would need to be developed for drainage in all passageways leading from the area of the stope. Then, conditions in each of these passageways would have to be carefully monitored while filling the stope to observe any areas of increased seepage. If significant step increases in the flow in any of these passageways occur, then the source of the seepage would need to be located and plugged before proceeding with the sludge disposal option. If this procedure identifies currently unknown openings connected to the stope, then the cost for this disposal option would increase, potentially by a significant amount.

It is necessary to limit the amount of free-standing water on the sludge. This can be accomplished with the construction of a water collection system of piping and sand bedding. This collection system should be installed in the laterals and cross-cuts at 6 Level near the plug locations along the east side of the stope.

This collection system can be combined with a decanting operation to remove excess water if water is found to pond in the stope between seasonal sludge filling periods. To accomplish this, a steel pipe would be lowered into areas of free-standing water in the stope from the access points at 5 Level. A submersible pump would then be lowered into the pipe to remove the free-standing water in the stope and to pump it to the 5 Level ditch for gravity flow to 9 Level and out the Kellogg Tunnel.

Other components of this option are more implementable. Collection and diversion of mine drainage to keep the majority of the flows away from the stope is implementable. Rehabilitating the Russell Adit could most likely be accomplished if the existing drift could be mined out and resupported or alternatively, a new parallel drift could be constructed to bypass the cave-in zones. Hauling of dewatered sludge to the Reed Landing could be implemented. Reconditioning of the laterals and in-mine haulage is also implementable, but would be more difficult because of the haul truck size limitations.

5.2 Effectiveness

The effectiveness of fully containing the sludge in the stope is uncertain unless complete plugging, placing of graded filters, and water testing is first performed to confirm the effectiveness of the stope to contain the sludge without loss or migration to other areas of the mine. It is likely that the main openings leading from the stope at 6 Level could be effectively plugged, but the presence of other unknown openings such as raises, diamond drill holes, and fractures in the rock could significantly increase the uncertainty for containment.

The effectiveness of containing the sludge is also dependant on the ability to prevent AMD from entering the stope. If significant quantities of AMD did enter the stope, the AMD could dissolve metals from the sludge, which could then be transported out of the stope to other portions of the mine and eventually end up at the CTP for re-treatment. Based on the results of the reconnaissance, it is not anticipated that significant quantities of mine water will enter the stope, and that effective groundwater control can be implemented for diversion of water from the stope. However, the long-term stability of the sludge in contact with mine water is recommended for more detailed evaluation if this option is carried into further design detail. Sludge dissolution studies should be performed to evaluate the long-term stability of sludge and its potential for future dissolution based on contact with AMD and with other mine water that is present in the area.

6.0 Cost Estimate

6.1 Sludge Dewatering Costs

The sludge must first be dewatered before it can be hauled to the Russell Adit. Sludge drying beds are recommended since they allow storage of the sludge for campaign excavation and haulage into the stope during favorable summer weather. Another dewatering option would be belt filter presses. This would be more costly and would require a storage area for the sludge when it could not be hauled into the mine. Table 1 summarizes the costs for dewatering the sludge using sludge drying beds, which were developed in the *Bunker Hill Mine Water Presumptive Remedy, July 1999,* document.

6.2 Hanna Stope Capital Costs

The capital cost for Hanna Stope sludge disposal, excluding sludge dewatering, is estimated to be $6,560,000. This cost includes rehabilitating the Russell Adit and 5 Level access points to the Hanna Stope. It includes several new drifts to gain access to the west side of the stope at 6 level for plugging and to allow future access for monitoring of areas surrounding the stope. It includes removing waste rock and construction of filter layers in selected areas of the base of the stope and plugging cross-cuts, laterals, and raises at selected locations around the perimeter of the stope. It also includes safety improvements to the service raise and Sullivan No. 2 Adit for emergency access into and out of the mine. The cost also includes improvements to the groundwater collection and drainage systems, and future monitoring and management.

6.3 Hanna Stope O&M Costs

O&M costs include excavating the dried sludge from the sludge drying beds and hauling and disposing the sludge in the Hanna Stope. It also includes costs to pump water from the sludge, water quality testing, maintenance of the underground facilities, and power for operation of the ventilation and lighting systems. These annual O&M costs are estimated to be $392,000 per year.

6.4 Cost Summary

Table 1 summarizes the costs to dewater the sludge using sludge drying beds and for disposal in the Hanna Stope. The total 30-year net present value (NPV) cost is $14,740,000.

TABLE 1
Sludge Dewatering and Disposal Cost Summary

	Capital Cost ($)	Annual O&M Cost ($/year)	Total 30-Yr NPV Cost[2] ($)
Sludge Drying Beds	1,160,000	65,000[1]	2,150,000
Hanna Stope Disposal	6,560,000	392,000	12,590,000
Totals	**7,720,000**	**457,000**	**14,740,000**

[1]Does not include sludge excavation and haulage, these costs are included in the Hanna Stope O&M costs.
[2]The 30-year NPV uses a 5 percent interest rate and no inflation.

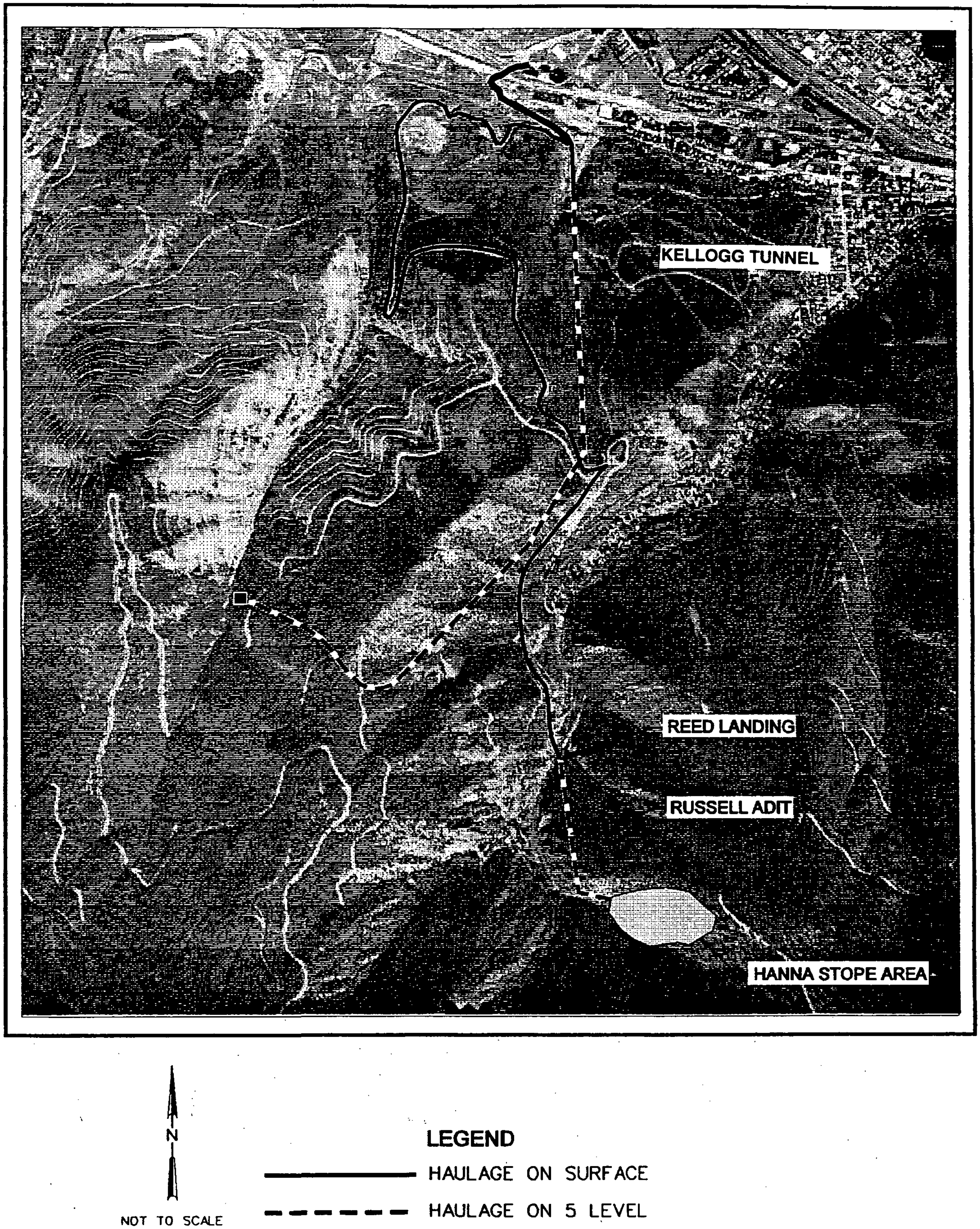

Figure 1
HANNA STOPE
LOCATION MAP

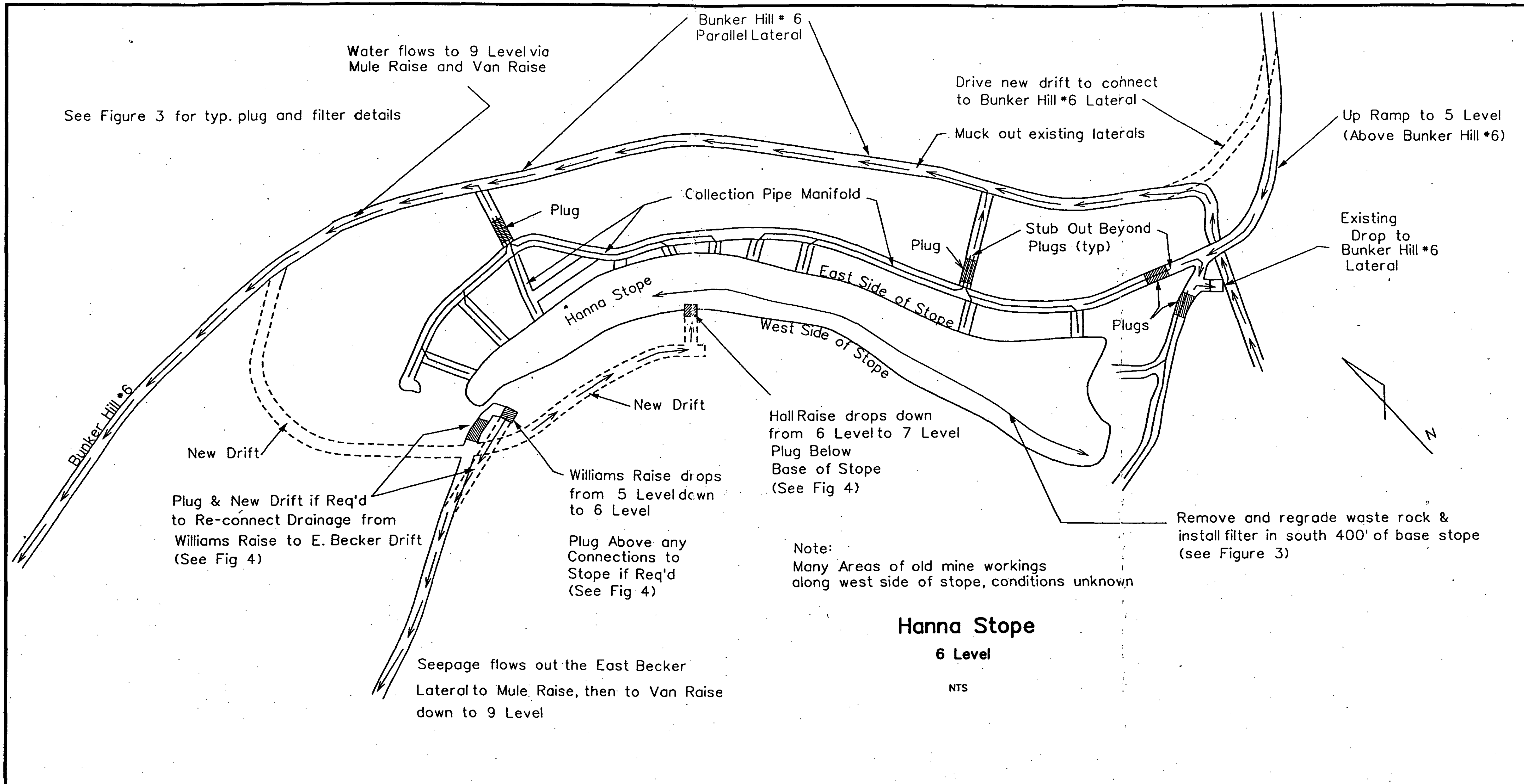

Figure 2
HANNA STOPE
6 LEVEL

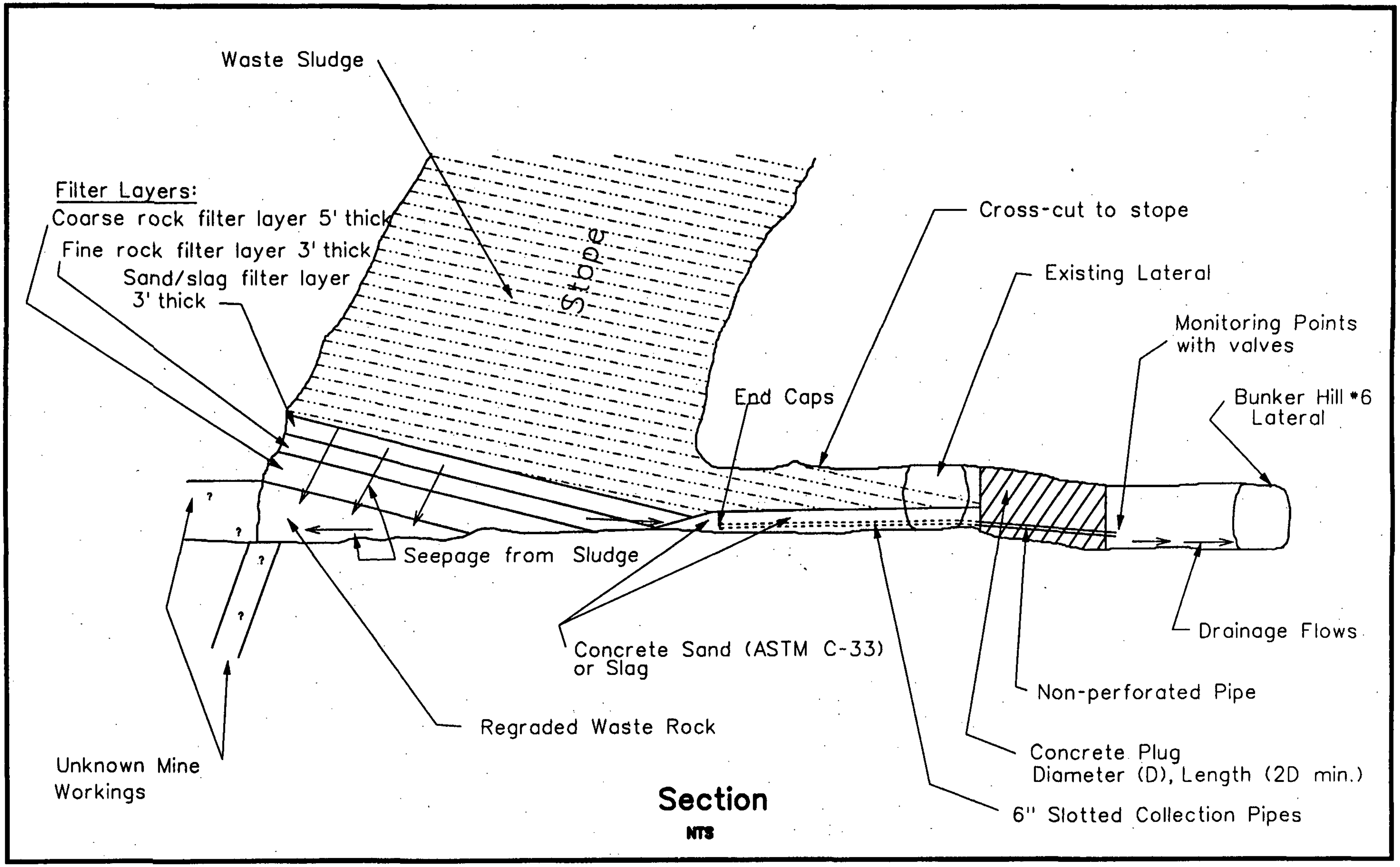

Figure 3
PLUG AND FILTER CROSS-SECTION AT SLOPE

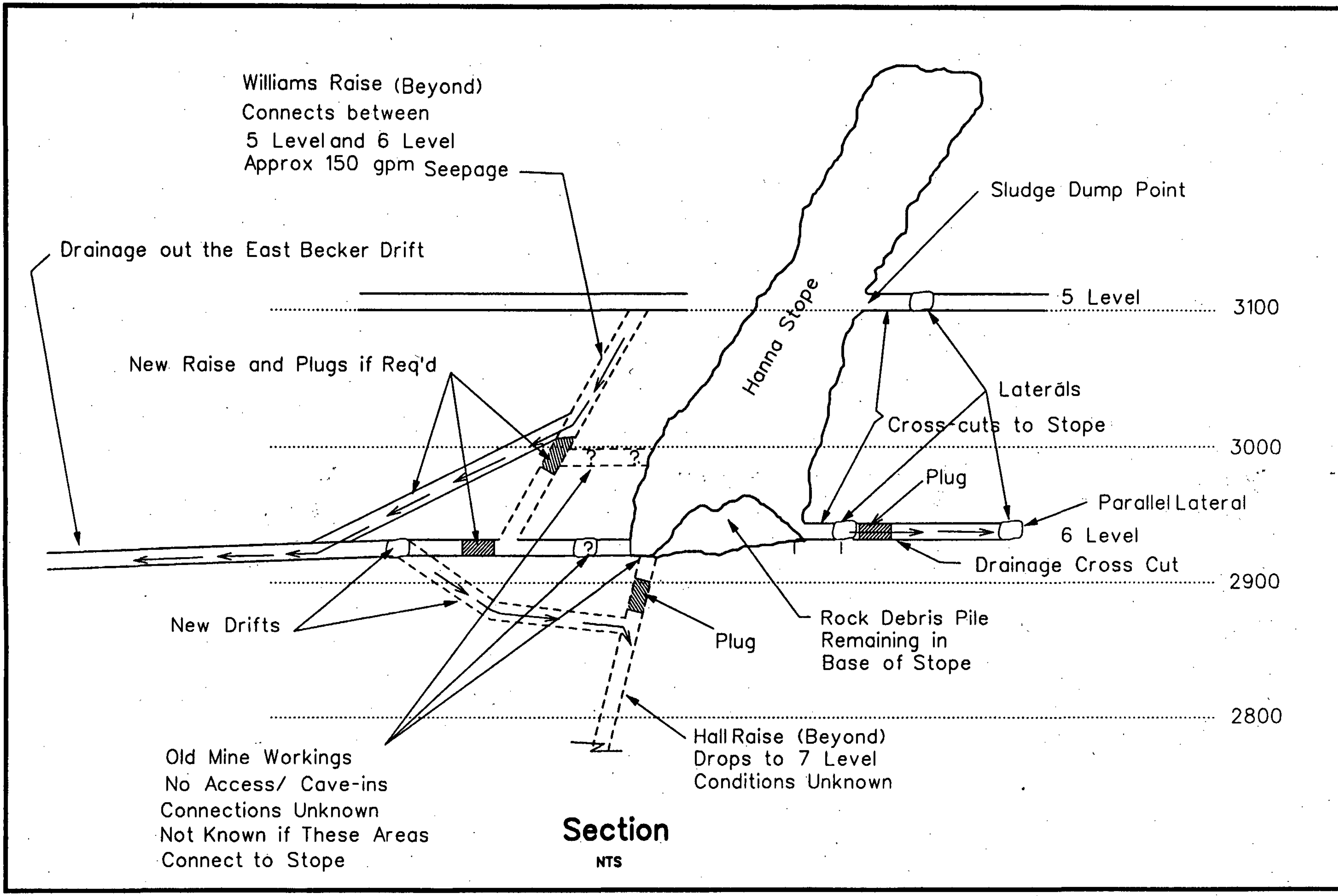

Figure 4
HANNA STOPE
TYPICAL CROSS-SECTION

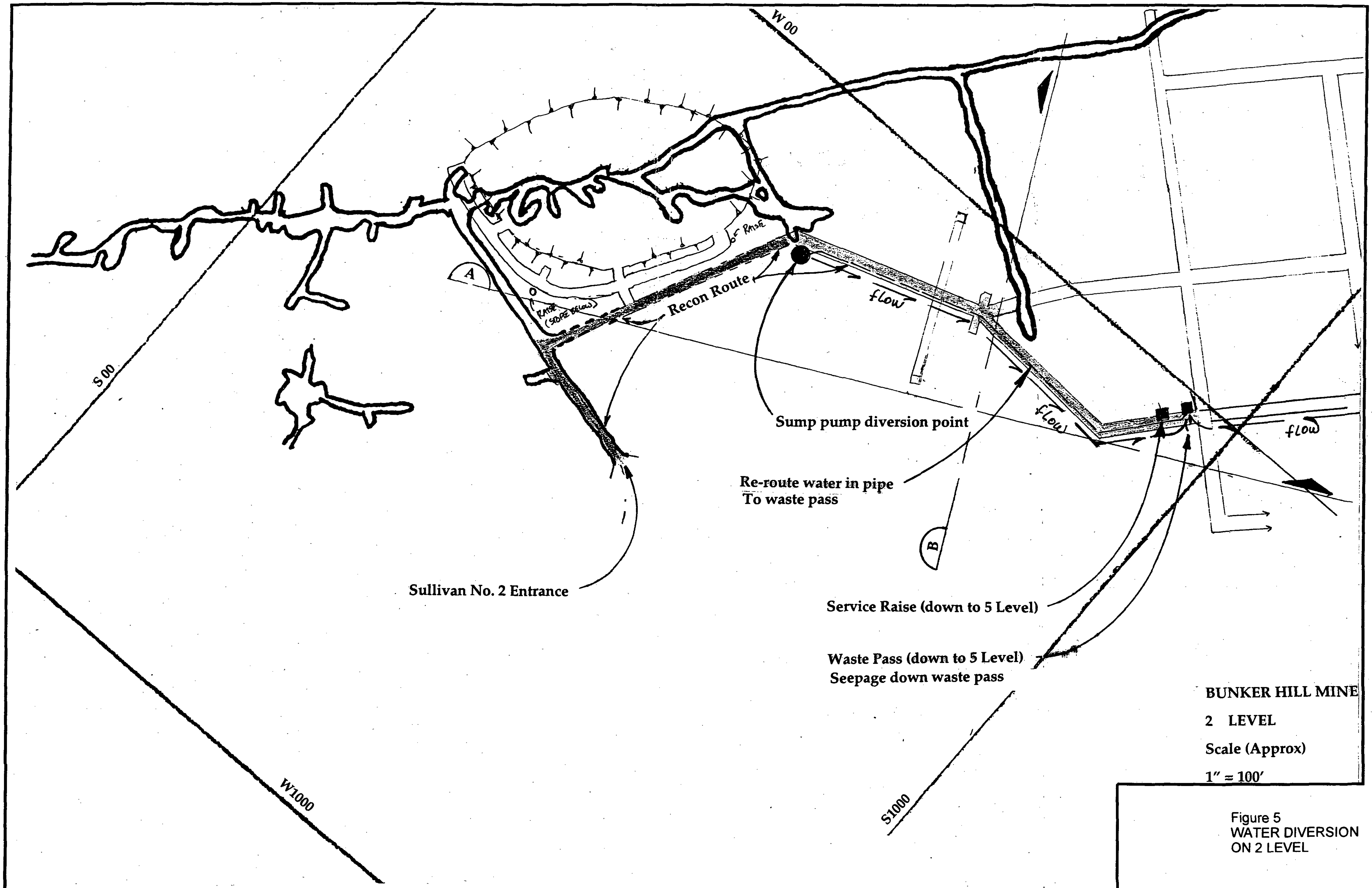

Figure 5
WATER DIVERSION
ON 2 LEVEL

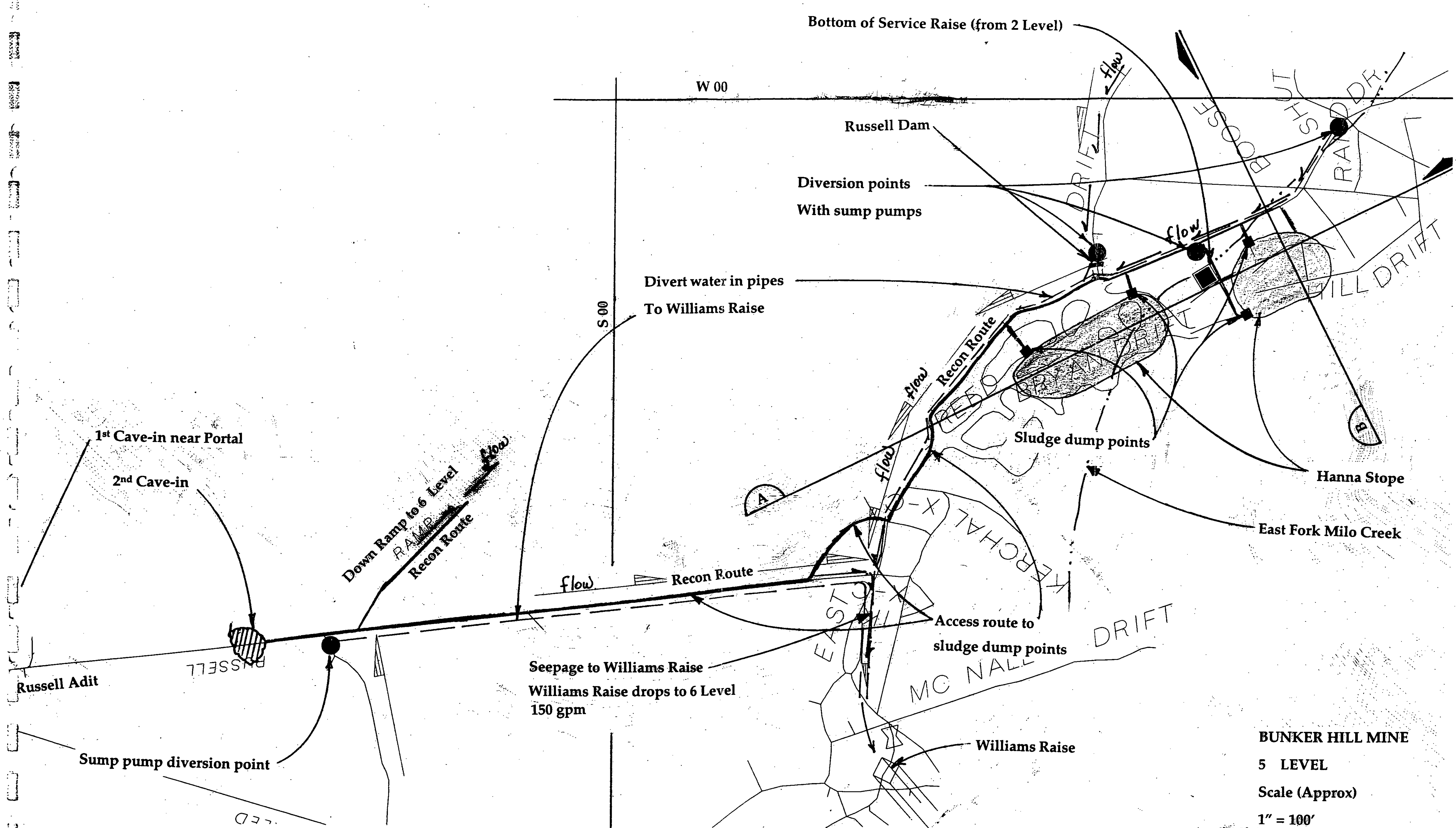

Figure 6
WATER DIVERSION
ON 5 LEVEL

APPENDIX A

Technical Memorandum: Field Reconnaissance of Hanna Stope

Field Reconnaissance of Hanna Stope

PREPARED FOR: Mary Kay Voytilla/USEPA

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Nick Zilka/IDEQ
Mike Thomas IDEQ
Mike Mahoney/US Army Corps of Engrs
Dale Ralston/University of Idaho
Bob Hopper/New Bunker Hill Mining Co.
Matt Germon/CH2M HILL
Travis Pyle/CH2M HILL
David Bunte/CH2M HILL

DATE: July 22, 1999

Purpose and Scope of Work

A reconnaissance trip was conducted on 6 July 1999 into the Bunker Hill Mine in Kellogg, Idaho. Of primary interest are the underground workings of the Russell Adit and Sullivan No. 2 Adit in the Milo Creek Basin area. A large underground opening known as the Hanna Stope is of specific interest for its potential as an underground depository for waste sludge. The sludge is a byproduct from the treatment process of acid mine water that is continually being collected and treated from the underground areas of the mine. Evaluation of this disposal option was identified as a high-priority issue in the Presumptive Remedy Workshop #2 held March 2 and 3, 1999, in Spokane, Washington. The purpose of the underground inspection was to gain a better understanding of the underground conditions, configuration, and characteristics of the Hanna Stope and the associated access adits and shafts so that a better assessment of feasibility and cost of this alternative could be established.

The purpose of this Technical Memorandum is to document the findings of the reconnaissance. The use of this information to evaluate the Hanna Stope as a location for sludge disposal will be presented in a subsequent Technical Memorandum.

The scope of work for the reconnaissance was previously identified in the Hanna Stope Reconnaissance Plan, prepared by Dave Bunte and Jim Stefanoff (CH2M HILL memorandum dated May 10, 1999). Briefly, the scope of work included the following information-gathering activities:

- Confirm potential locations for plugging the lower portions of the stope for sludge containment. Evaluate plugging method and stress conditions under which the plug must function.
- Determine sources and approximate quantity of water flow into the stope for potential control or diversion.
- Develop an approach for containment and removal of water that accumulates in the stope.
- Determine requirements for cleanup and rehabilitation of the Russell Adit.
- Observe general condition of mine workings with regard to potential improvements for long-term operation and safety.

As part of the work effort, four water quality samples were taken from various levels of the mine during the reconnaissance trip. This sampling effort, and results of analytical testing, will be presented and summarized in a separate technical memorandum.

Personnel

The following people participated in the reconnaissance inspection:

- John Riley – Hydrogeologist
- Bill Hudson – Mining geologist and site safety coordinator
- Willie Lujon - Mine Safety and Health Administration
- Nick Zilka – Idaho Division of Environmental Quality
- Travis Pyle – Civil Engineer CH2M HILL
- Jay Dehner – Geotechnical Engineer CH2M HILL
- Ken Green – Geotechnical Engineer CH2M HILL

Timing and Routes

The inspection trip began the morning of July 6, 1999, and concluded about 6:00 p.m. that evening. Originally scheduled for two days, the trip was condensed into one long day to provide continuity of evaluations and to minimize health and safety concerns.

The team assembled at the site at 8:00 a.m. A safety inspection and brief training of essential safety equipment was held before proceeding into the mine. After the proper equipment was prepared for use, the team traveled to the Sullivan No. 2 entrance for entry into the mine at 2 Level. The general plan was to inspect the upper levels of the mine first, then work our way down through the various sublevels to the bottom elevation of the Hanna Stope at 6 Level. The objective was to collect as much information as possible about the configuration and condition of the adits, drifts, laterals, and shafts throughout the various levels of the mine in the areas adjacent to the Hanna Stope.

A summary of the reconnaissance route and observation points is presented in Table 1. Figures 1 through 3 (for 2 Level, 5 Level, and 6 Level, respectively) show the routes walked during this reconnaissance trip. The following discussion relates the reconnaissance path and observations at various inspection points along the way.

Mine Entrance at Sullivan No. 2 to Service Raise

The team entered the mine on the east hillside about 100 to 200 feet (vertically) above Milo Creek at the Sullivan No. 2 entrance, located near the confluence with the South and East Forks of Milo Creek. The elevation at the mine entrance is about elevation 3450. Some caving had occurred near the portal area but conditions were dry and entry was judged to be safe.

The heading at the entry was about 30 degrees (azimuth). At a distance of about 150 feet into the adit, we turned onto a downramp that sloped at about a 10 percent grade at a heading of about 130 degrees. We followed this heading for a distance of about 300 feet, where the adit divided into other headings and areas of mine workings. Only minor seepage was encountered into the adit to that point.

From this juncture, we then followed a heading of about 165 to 190 degrees for a distance of about 450 feet to the location of the service raise. The service raise allows ladder access to lower workings and elevations in the mine. Increased seepage was encountered along this section of the adit. The seepage occurred primarily from joints, fractures, and seepage paths in the natural rock mass, but it was concentrated predominantly in certain areas as a result of old borings, raises, and other mine workings. Seepage has been found to correlate well with seasonal changes in quantity of surficial flow in the stream.

The service raise consists of an inclined shaft (approximately 6 x 8 feet) dipping at about 60 degrees from horizontal and at an azimuth of about 220 degrees. The service raise interconnects the Sullivan No. 2 level (approximate elevation 3440) with the various sublevels down to 5 Level (5 Level, approximate elevation 3100). A parallel waste pass also interconnects all sublevels, and currently provides a pathway for water diversions down to 5 Level.

Intermediate Sublevels Between 2 Level and 5 Level along Service Raise

We entered the service raise shaft at 2 Level and progressed down, stopping at selected sublevel areas of the mine where conditions were judged to be safe to get off the ladder and onto the adjacent sublevel bench areas. The ladder at the service raise is constructed of steel rails, supports, and rungs. It shows some signs of scaling and deterioration but was in safe condition for our work.

At several of the sublevels along the service raise shaft, various access laterals were accessible to gain entry around the perimeter and to the edge of the large underground caverns comprising the Hanna Stope. For safety reasons, we could not easily get close to the edge of the stope in many areas. However, we could view the cross-cut openings into the stope, and we could determine the approximate distance across the stope using reflected laser signals from a laser rangefinder targeted at areas on the opposite wall of the stope.

We obtained width measurements where it was possible to gain access to the stope. We also obtained an approximation of the length of the stope area by laser measurements in the stope and along the perimeter mine laterals adjacent to the stope. See Figures 4 through 6 for sketches of the approximate stope configurations and the measurements that were taken.

The Hanna Stope is composed of several openings or caverns in the rock mass. The stope is a large interconnected continuous cavity at 6 Level, but consists of distinctly separate vertical stopes extending up into the rock mass at higher levels. At least one of the stopes is estimated to extend up to about elevation 3400 along the area of the mine workings. Figures 7 and 8 (Sections A and B, respectively) show the arrangement of the stope along its longitudinal axis or strike direction and along an alignment that is perpendicular to the strike.

All of the stopes are inclined at about 60 degrees from horizontal, which is the approximate orientation of the geologic fault that these mine workings follow. The stope is believed to dip to the southwest at an azimuth of about 240 degrees and is arcuate in shape, with the stope extending longitudinally from southeast to northwest (see Figure 3). The stope that was observed at this intermediate level (second sublevel below 2 Level) is believed to be centrally located along the line of stopes that make up the Hanna Stope. This stope broadens out longitudinally into a much larger stope at about elevation 3050 and below, as can be observed at 6 Level (see Figure 7). Above elevation 3050, the stope is believed to be separated by country rock pillars in between the stopes, resulting in several distinctively separate caverns at the upper elevations.

As shown in Figure 4, measurements taken of the central stope area at the second sublevel below 2 Level indicated that the stope was about 135 feet long and was oriented in a northwest-southeast direction. The width varied from about 90 feet wide at the southeast end to about 50 feet wide at the northwest end of the stope. The average width was approximately 65 feet. This central stope area was found to open both upward and downward at this level. See Figures 7 and 8 for the approximate position and orientation of the stope.

Most of the groundwater observed at the intermediate levels appears to originate from the 2 Level areas. The flow then migrates to the various sublevels via ditches along the bottom of the adits and seepage into joints and fractures, but primarily by drainage down the waste pass to 5 Level. From there, the water flows by gravity along the adits on 5 Level to the Williams Raise, where it then drops to 6 Level, as shown in Figures 2, 3, 5, 6, and 8.

Other drainage areas, such as the Russell Adit, Old and New East Reed Drifts, and others contribute to the total quantity of flow that drops down the Williams Raise to 6 Level. Therefore, the total seepage at this discharge point represents a collection of water from several other areas of the mine, in addition to the seepage that originates in the vicinity of the Hanna Stope. The total flow at the Williams Raise on 5 Level varies seasonally, but was estimated to be about 150 gallons per minute (gpm) during our visit.

A relatively small amount of water presently seeps or drains directly into the stope at some locations along the intermediate sublevels of the mine. In most locations, however, the water has been diverted along the adits to drainage paths (primarily the waste pass) that avoid the stope. Seepage into the service raise was minimal.

5 Level Observations

The bottom of the service raise is at 5 Level, which is also the bottom of the parallel waste pass where most of the groundwater passes from higher levels down to 5 Level. It is also 5 Level that is proposed as the level for the entry of waste sludge into the mine for deposition in the Hanna Stope. As previously discussed, much of the groundwater that seeps and flows from the upper levels of the mine workings is presently collected on 5 Level, where it is routed by gravity flow to the Williams Raise, which is located at the northwest end of the stope. Figures 1 through 6 show the areas of concentrated groundwater flows, flow directions, approximate flow quantities, and locations of drops to lower levels.

At the base of the service raise, a stope was examined near the southeast end of the workings. This stope was located within about 50 feet of the service raise shaft and with a series of measurements was determined to be about 80 feet wide by 100 feet long. The stope also opened both upwards and downwards from 5 Level.

This southeast stope could be examined from several different access points around the perimeter of this cavity. The approximate dip and orientation of the stope could be observed from several of the vantage points at this level. The natural rock was observed to be generally of excellent quality throughout this area of the mine workings. As observed from this level, very little water was found to be entering the stope from 5 Level or from within the stope area.

At Level 5, another stope was observed about 150 feet in a northwestern direction from the southeast stope (see central stope, as labeled on Figure 5). It is believed that all the stopes open up to a common cavity at the base near 6 Level, but that they were not connected at 5 Level (see Figure 7). The central stope area was found to be approximately 210 feet long and distance shots indicated the width to be about 65 feet. This stope also opened both upward and downward from the 5 Level access points. The natural rock quality was excellent in this area and relatively little water was found to be entering the stope from 5 Level or within the stope area. It is believed that other stopes may exist farther to the northwest, but the size or dimensions of these areas was not observed at 5 Level.

From the central stope, we walked in a northwest direction along the east side of the stope area until we reached the Russell Adit. Major flows along this section of 5 Level originate from above the Russell Dam along the Old East Reed Drift, from fracture zones and diamond drill holes along the New East Reed Drift, and from the Old Sullivan workings. All drainage areas gravity flow to the Williams Raise in a northwesterly direction. See Figures 1 through 6 for the areas of concentrated groundwater flows, flow directions, approximate quantity of flow, and locations of drops to lower levels.

At the Russell adit, we walked north for a distance of about 600 feet, where we encountered the ramp that leads down to 6 Level from the Russell Adit. Before continuing down to 6 Level, we walked farther north along the Russell adit until we reached the back side of a cave-in (called out as the "second cave-in" on Figure 2). The second cave-in is estimated to be located about 600 feet into the Russell Adit from the portal.

We inspected the condition of the adit through this section and observed the back side of the cave-in area. The roof of the caved area extended to an estimated height of about 30 feet or more and was judged to be unsafe to enter. It looked as though the top of the caved debris may not extend to the roof of the cavity, and that it may be possible to pass over the top of the cave-in area.

The restoration of the adit would require the repair of the second cave-in area or would require that a new adit be constructed to prepare a path around the unstable areas. It is our understanding, however, that the second cave-in has resulted from poor-quality rock associated with the Dull fault zone that crosses the adit at this location. Consequently, other potential routes may be just as difficult to re-establish across the fault zone. The poor ground conditions result from associated fracture zones subparallel to the fault and more pronounced rock joint patterns, which lead to the more broken ground conditions, are evident in this area. This area would require more extensive bolts, support mats, and timber cribbing than other areas observed on 5 Level.

6 Level Observations

From the Russell Adit, we walked about 1500 feet down a 10 to 12 percent grade to 6 Level. The heading of this ramp was about 135 degrees near the north end to about 220 degrees near 6 Level workings. We entered the 6 Level workings near the southeast end of the stope, and then worked our way along laterals that parallel the east side of the stope to the northwest. The stope was large and very long at this level. The width of the base of the stope was determined at several of the cross-cut access points to the stope off of the perimeter lateral. The width varied from about 50 feet to 70 feet (see Figure 6). Throughout 6 Level, the stope was found to open upward but not downward.

Entry was not made into the stope area because of safety concerns associated with falling rock debris. Our access for observation of the stope was along the east side. Observation of the condition of the laterals, stope, and groundwater conditions is good along the east side, and nearly all of the approximately 600-foot length of the stope area could be walked and inspected. No access was available to the west side of the stope and the area could not be viewed because of the waste rock piles that remain in the base of the stope.

Rock debris has accumulated in the base of the stope and the waste rock piles were estimated to vary from 20 to 40 feet in height along most of the stope. The rock size of the accumulated material in the base varied greatly along its length. In some areas, the rock waste was relatively fine, with the majority of the material being less than 2 to 3 inches in diameter. In most areas, however, the maximum size of the rock varied from about 1 foot to 6 feet. In one area, a large rock block the size of a house was noted to have fallen to the bottom of the stope and was resting against the inclined face of the stope.

It was noted that the gradation of the rock mass varied so greatly that it would be difficult to construct a filter that was adequately sized to prevent migration of silt-sized sludge fines unless several separate filter layers were used. Construction of such a filter would require starting with a very coarse gradation and building successively finer layers, and would probably require access by earth-moving equipment into the stope to prepare the surface and place the filter material.

Groundwater was being collected from various points along the east lateral and from the stope at 6 Level. Most of the water at 6 Level is collected along various drainage paths leading down from the upper levels of the mine, as previously described. A small portion of this drainage originates directly from fissures or joints in the rock mass.

On the east side of the stope at 6 Level, the water drains by gravity to the northwest along Bunker Hill lateral #6 (see Figures 3 and 6). The water flow at the southeast end of the stope was estimated to be about 25 to 30 gpm and originates from the southeast stope and from the ramp leading down from 5 Level. The flow from the ramp drops down to the Bunker Hill #6 lateral, as shown in Figure 6.

Each of the cross-cut laterals from the stope were estimated to be flowing at a rate of about 10 to 20 gpm, for a combined flow of about 50 to 60 gpm at the northwest end of the Bunker Hill #6 lateral. From the northwest end of the Bunker Hill #6 lateral, the water flow drops into the Van Raise, where it combines with flow from the Williams Raise and possibly other drainage areas along the west side of the stope, where it then drains down to 9 Level. From there, the water flows by gravity to other areas of the mine located farther to the northwest. The estimated combined flow of the Bunker Hill #6 drainage and the flow from the Williams Raise is about 180 gpm.

The east side of the stope is opposite the hanging wall and one might expect to find the greatest accumulations of debris along the base of the inclined wall of the stope. It is our understanding that much of the rock piles that remain at the base of the stope are remnants of the rock that was being mined. Excavators removed the rock from the east side, but would venture only a short distance out into the stope because of safety concerns about falling rock. The debris noted in the bottom of the stope during our visit is, therefore, probably a mixture of the remnants of the rock being mined and additional rock that has fallen since mining has ceased.

Although the debris was noted to be 20 to 40 feet in height in the base of the stope, most, if not all, of the cross-cut access points to the stope at 6 Level are still open. The inside of the stope could be viewed at most of the stope access locations. Although not counted, it is estimated that 12 draw points entered the base of the stope along the east side at 6 Level. Three interconnected cross-cuts lead away from the east side of the stope to a main lateral, with two older cross-cuts continuing to a second parallel lateral located about 100 feet east of the stope. This lateral presently collects water where it is gravity drained to the Mule Raise and eventually down to the Van Raise.

If the stope were to be used for storage of sludge, three cross-cuts and the ramp leading down from 5 Level would have to be permanently plugged to seal off the area where sludge would be stored. The base of the stope should also be drained and provisions for a permanent drainage/water collection system should be incorporated into the design for plugging these cross-cuts as well.

It is our understanding that old mine workings also exist all along the west side of the stope at 6 Level. These workings are no longer accessible because of caved-in areas along the drifts and expansion of the stope into part of the old workings. The drifts and various cross-cut access points to the stope are apparently about 8 feet lower in elevation along the west side of the stope and may have been constructed during more than one period of mining activity. The records of the mine workings along the west side are not complete. Consequently, a good knowledge of the location and extent of the workings and the interconnection of these workings with other drifts and raises that lead down to lower levels in the mine is not available. It is believed, however, that drainage from the west side of the stope exists and is presently connected, via the East Becker Drift, to 7 Level and lower. Other unknown interconnections may also exist.

It is important that these potential connections be identified if sludge is to be stored in the Hanna Stope so that these passages can be adequately filtered and/or plugged. The sludge will be subject to as much as 200 feet of hydraulic water head, and the sludge will readily pipe or erode through voids if such voids exist in the drainages and passageways that lead away from the base of the stope. Because access is not available to the old mine workings along the west side of the stope and little is known about the Hall Raise and interconnected passages from the stope to the Williams Raise, these conditions represent significant unknowns at this time. Additional knowledge can potentially be gained by performing additional exploration, such as making a new drive around the northwest end of the stope from the Bunker Hill #6 lateral to the Williams Raise and possibly to the Hall Raise. The drainage passages would then need to be systematically plugged to contain the sludge. Additional investigation and experimentation by adding water to selected areas of the stope and careful monitoring of the results may provide more information about the possible connection of the west side of the stope with other areas of the mine.

Return to Sullivan No. 2 Entrance and Inspection of the Russell Adit Portal Area

After leaving 6 Level, we returned along the same routes to 5 Level. At 5 Level, we ascended back up to 2 Level via the service raise near the southeast end of the stope area. While climbing back up the ladder, we estimated the vertical distance between the various sublevels below 2 Level as shown on Figures 7 and 8. We did not attempt to access the third sublevel because of poor access conditions from the service raise. We did, however, stop at the second sublevel and the first sublevel below 2 Level. The Hanna stope was not observed above the second sublevel below 2 Level. We returned to the Sullivan No. 2 Adit entrance via the same route from which we entered the mine.

On the way back down the valley, we stopped at Reed Landing, which is the location of the entrance to the Russell Adit. We inspected the portal area and walked back along the adit to the first cave-in area. We noted that the distance to the first cave-in was about 150 feet from the entrance. The first 130 feet of the adit is concrete encased because of poor-quality rock near the portal area. It was noted that the last panel (130 feet into the mine) had deflected several inches because of external soil pressure and that soil and rock were exposed behind the joints. This area would likely require repair if the adit were to be used in the future. The adit was noted to be about 9 feet wide and about 10 feet in height at the portal.

The first cave-in area appeared to be similar to the second cave-in observed from inside the adit. It is possible that a space exists over the top of the first cave-in but we did not enter because it was not considered safe to enter the caved area. The first cave-in near the portal is associated with poor ground conditions near the surface in that area.

A small area was noted around the portal where materials could be stockpiled. Stockpiling may be required for removal of debris from inside the adits if repairs were to be made. It was estimated that it might be much more cost effective to repair the cave-in areas by excavating the overburden soils at the portal rather than by resupporting the existing adit or making a new drive around the cave-in area. If the overburden soils were to be removed, a substantial area near the portal would be required for stockpiling of rock materials from this excavation. It is our understanding that disposal of the portal overburden material can be done off of the face of the main Reed Landing.

TABLE 1

Routes and Observation Points	Stope Dimensions/Plugging	Groundwater Diversion	Groundwater Collection & Routing	Access for Sludge Disposal	Condition of Adits	Safety
Enter Sullivan No. 2					•	•
Walk to Service Raise		•	•		•	•
Sublevel Inspection	•		•			•
5 Level Inspection	•	•	•	•	•	•
6 Level Inspection	•	•	•	•	•	•
Russell Tunnel Inspection	•	•	•	•	•	•

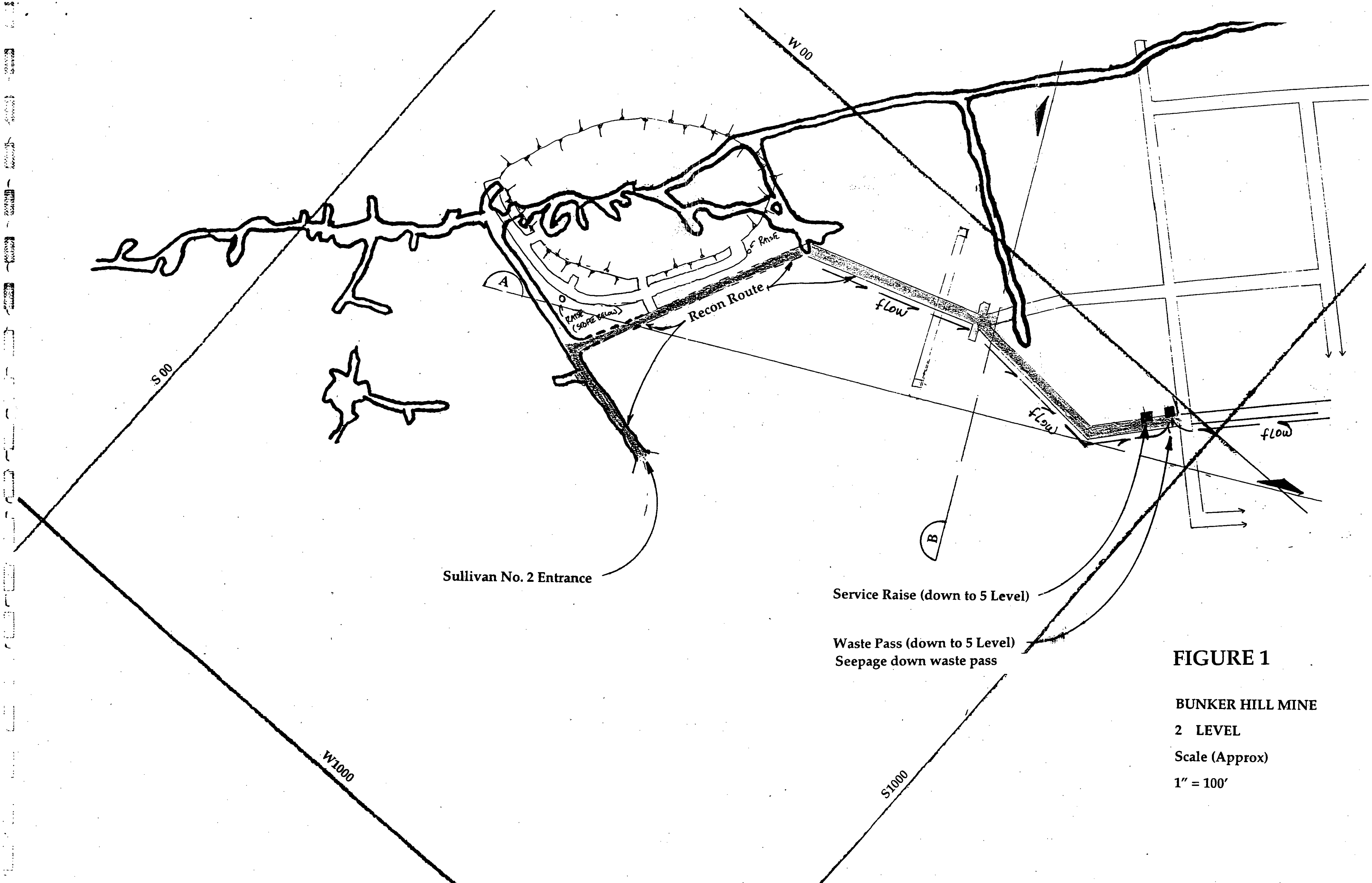


FIGURE 1

BUNKER HILL MINE

2 LEVEL

Scale (Approx)

1" = 100'

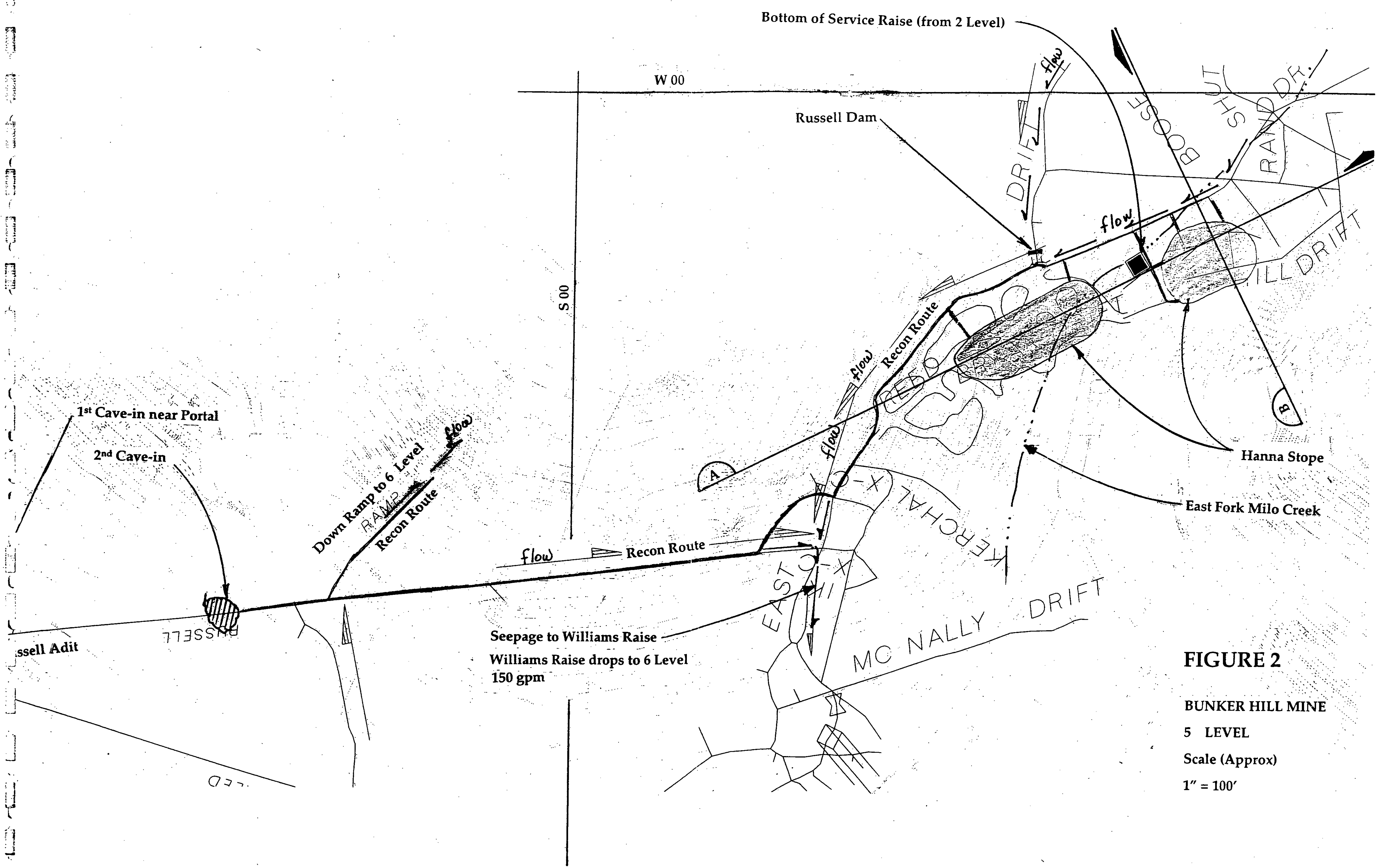


FIGURE 2

BUNKER HILL MINE

5 LEVEL

Scale (Approx)

1" = 100'

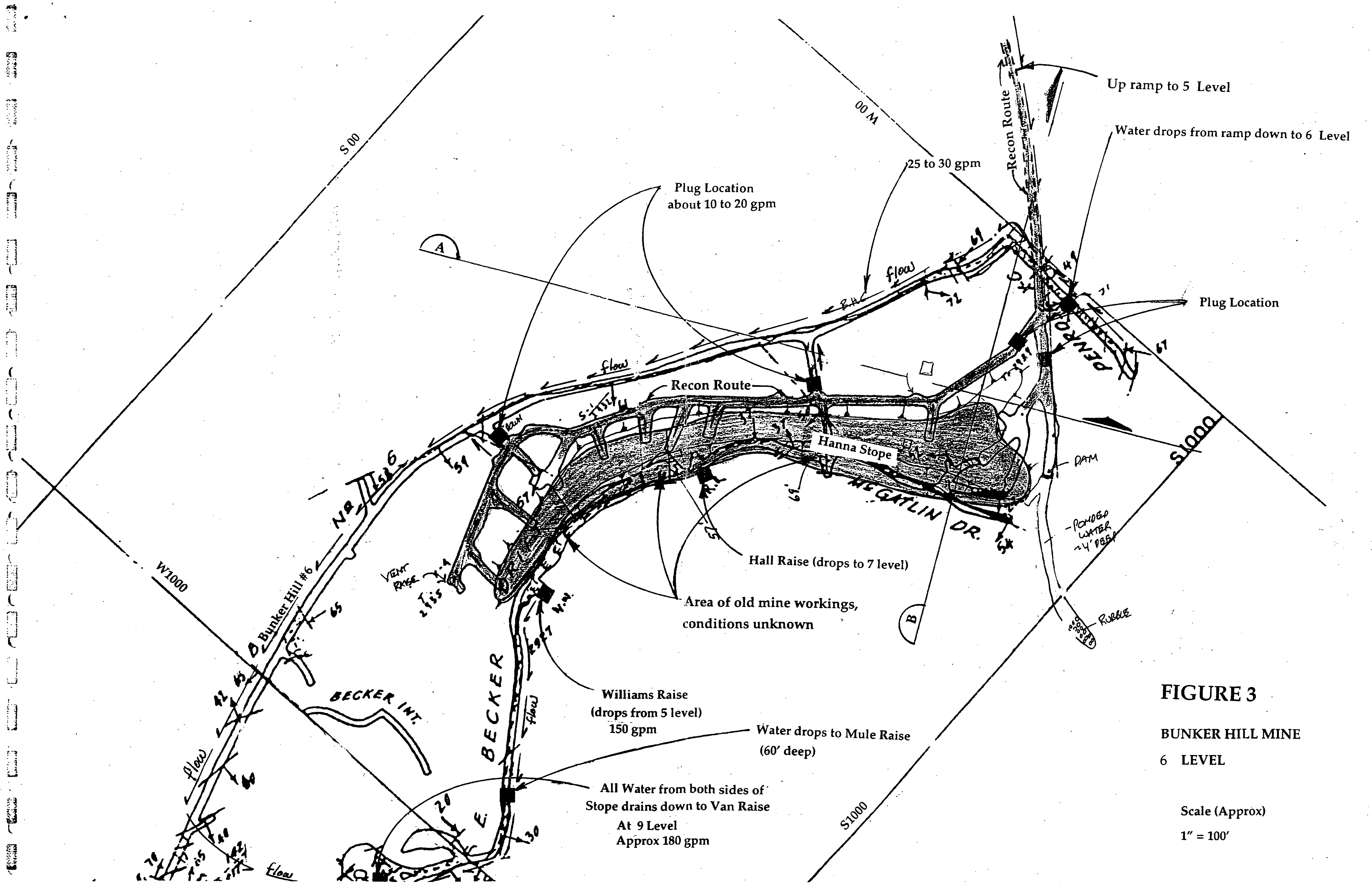


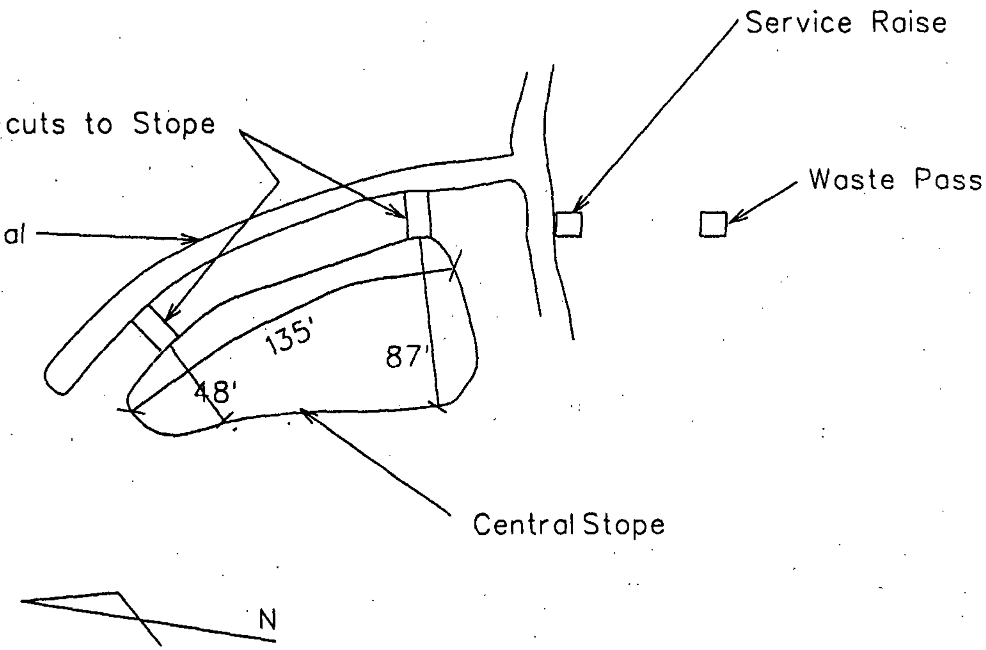
FIGURE 3

BUNKER HILL MINE

6 LEVEL

Scale (Approx)

1″ = 100′



Hanna Stope

Second Sublevel Below 2 Level

NTS

Field Notes

FIGURE 4

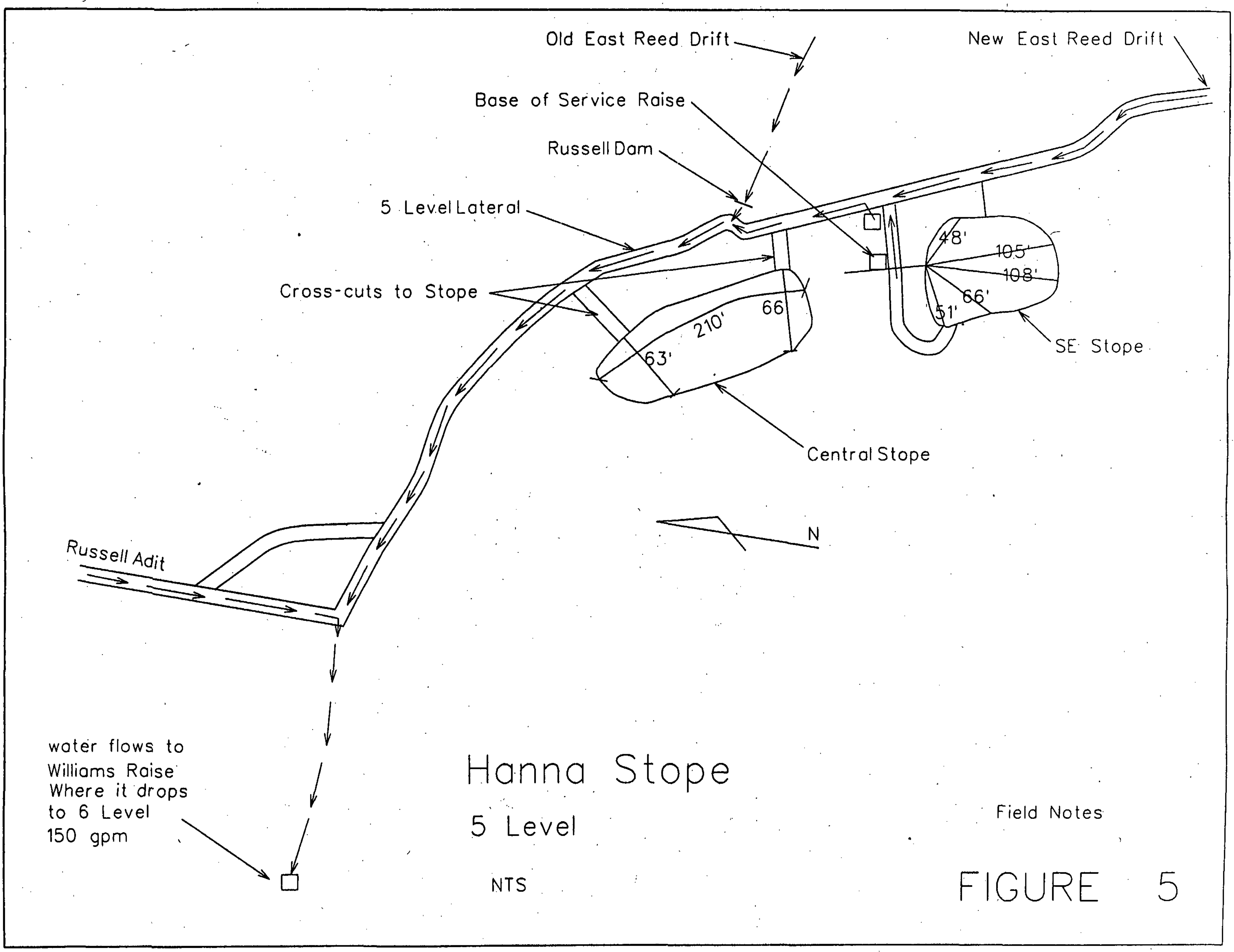
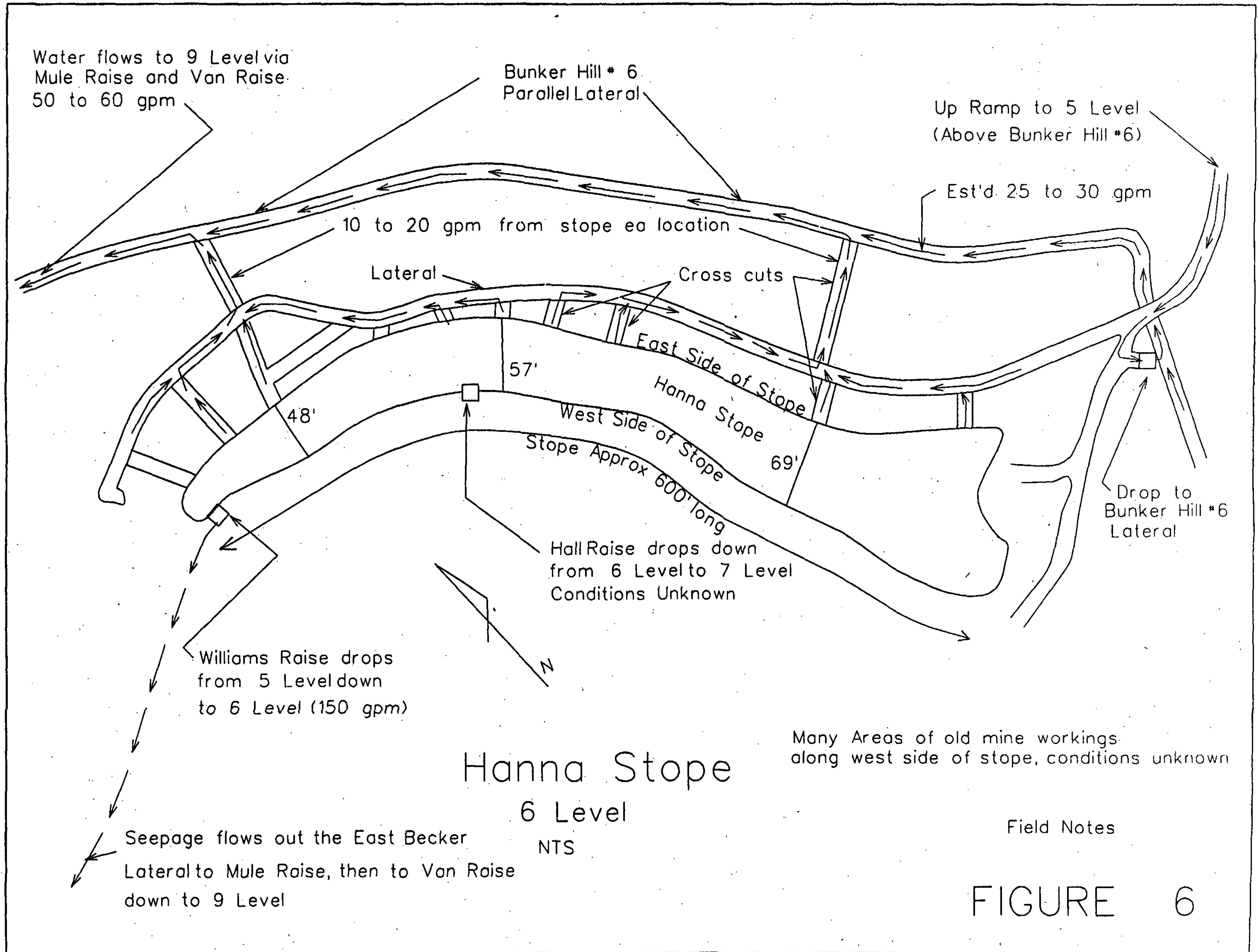
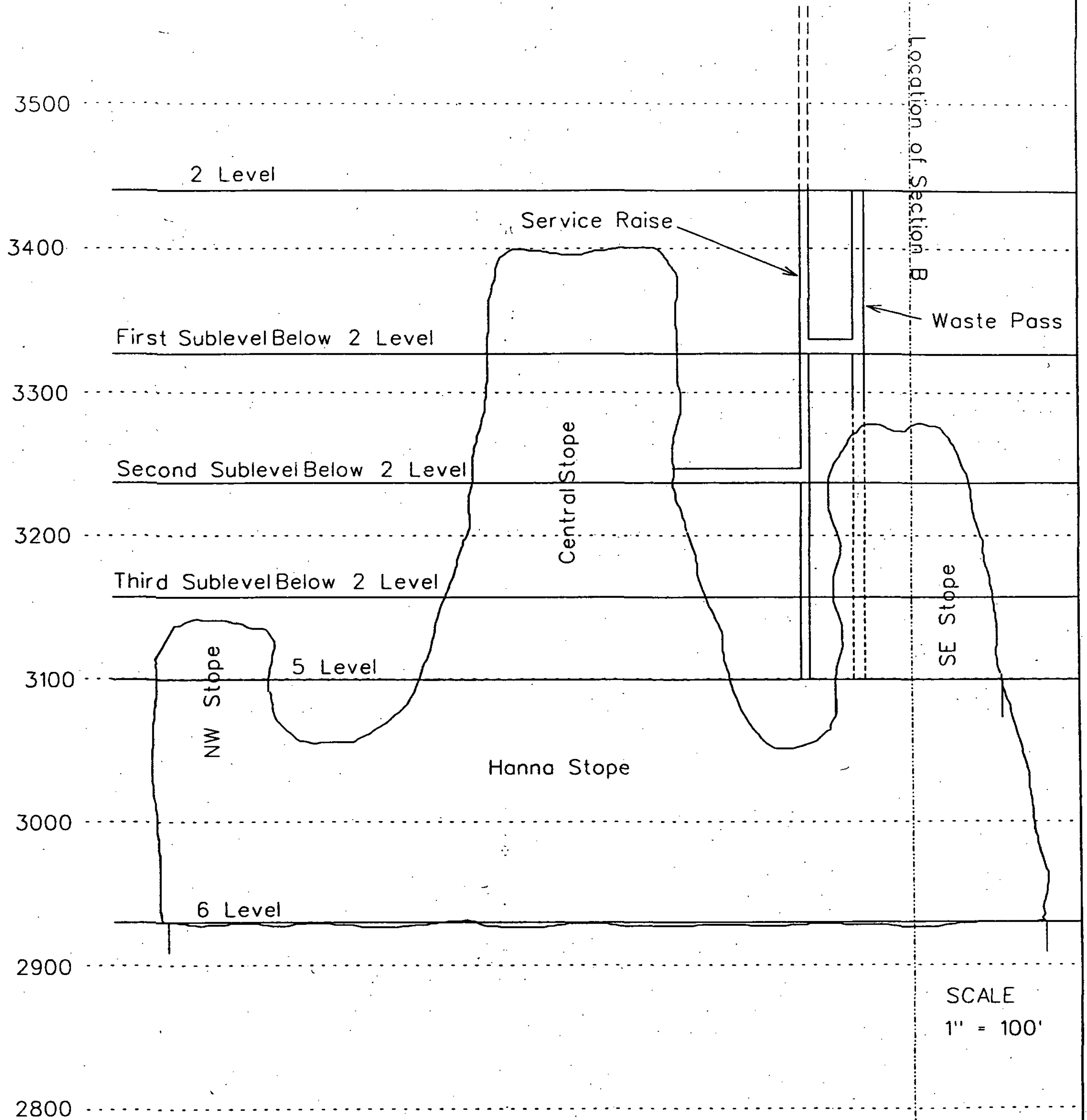

Old East Reed Drift
New East Reed Drift
Base of Service Raise
Russell Dam
5 Level Lateral
Cross-cuts to Stope
48'
105'
108'
66'
51'
SE Stope
66
210'
63'
Central Stope
N
Russell Adit
water flows to
Williams Raise
Where it drops
to 6 Level
150 gpm
Hanna Stope
5 Level
NTS
Field Notes

FIGURE 5



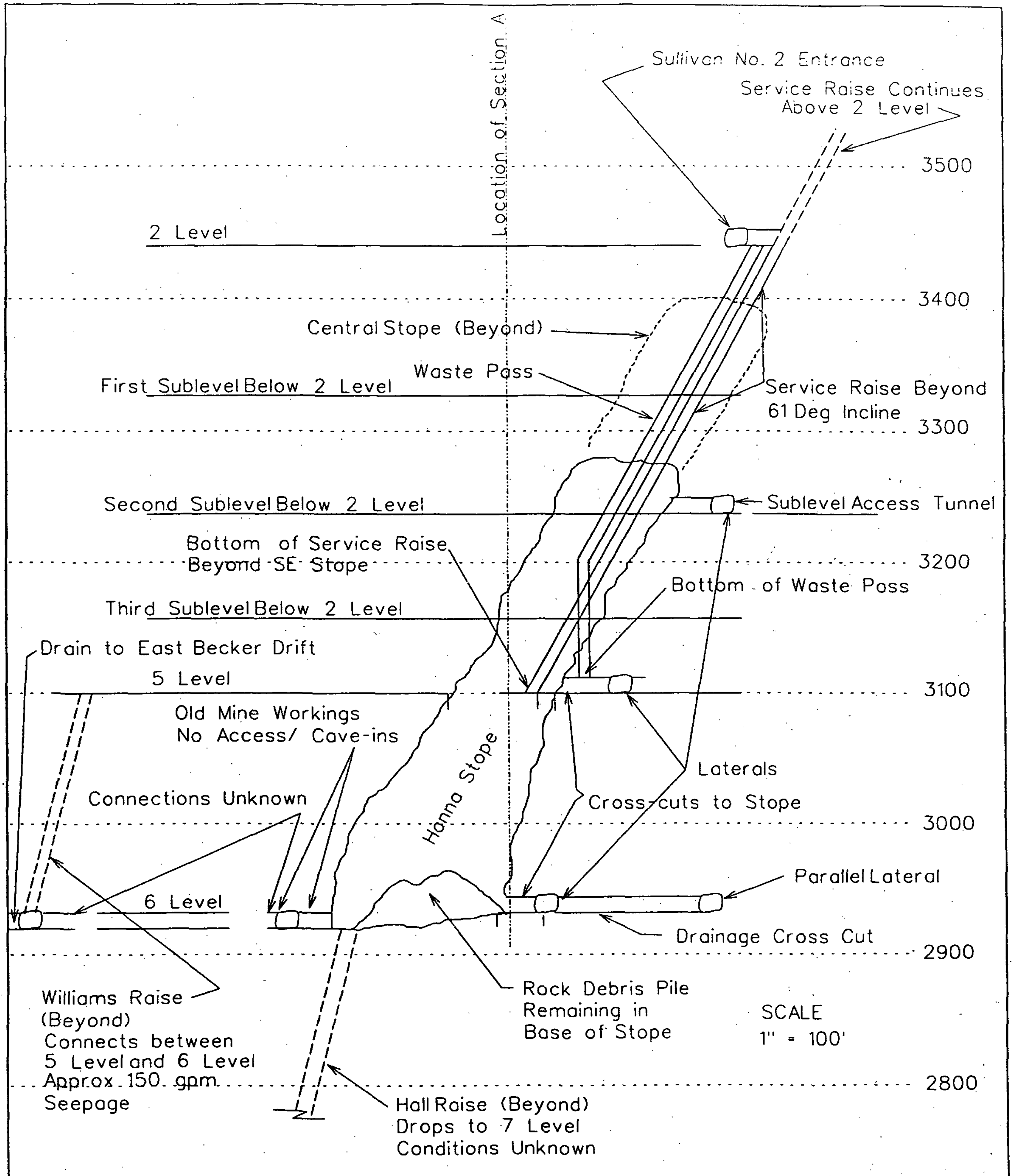
Hanna Stope
6 Level
NTS

FIGURE 6



SECTION A

FIGURE 7



SECTION B

FIGURE 8

APPENDIX B

Cost Estimate

Bunker Hill
Acid Mine Drainage
Disposal of Dewatered Sludge in Hanna Stope
Order of Magnitude Cost Opinion

DATE: 27-Mar-00
PROJECT NO.: 148562.02.01
ESTIMATE BY: M Jackson

	DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
	General				
1.0	Safety inspection of all from adits, laterals &raises to be used	160	CREW-HR	$60	$9,600
2.0	Scale/bar loose rock from all adits, laterals & raises to be used	160	CREW-HR	$85	$13,600
3.0	Temporary lighting for construction 6 Level, 5 Level, and 2 Level	1	LS	$20,000	$20,000
4.0	Repair areas with safety problems	160	CREW-HR	$150	$24,000
	Prepare Base of Stope				
5.0	Drive new lateral around NW end stope	650	LF	$750	$487,500
6.0	Drive new drift to connect between E Becker and Williams Raise	150	LF	$750	$112,500
7.0	Drive new drift to connect #5 ramp to Bunker Hill #6 Lateral	200	LF	$750	$150,000
8.0	Exploratory drilling/grouting to find workings	800	LF	$20	$16,000
9.0	Muck out existing laterals where required	250	CREW-HR	$95	$23,750
10.0	Establish baseline flow conditions in all laterals surrounding stope	210	CREW-HR	$60	$12,600
11.0	Install flow measuring devices in laterals	6	EA	$2,000	$12,000
12.0	Install sand bedding for collection manifold	910	CY	$30	$27,300
13.0	Install collection manifold piping	2,000	LF	$20	$40,000
14.0	Install sand cover over collection manifold	2,300	CY	$30	$69,000
15.0	Remove waste rock from critical areas along west side of stope	13,000	CY	$20	$260,000
16.0	Construct filter in critical areas	10,000	CY	$75	$750,000
17.0	Pressure wash and clean at plug locations	7	EA	$500	$3,500
18.0	Install concrete plugs with piping	7	EA	$25,000	$175,000
	Water Diversion at 2 Level and 5 Level				
19.0	Sump Pumps	5	EA	$2,000	$10,000
20.0	Piping (4")	3,050	LF	$15	$45,750
21.0	Install electrical for pumps	1	LS	$15,000	$10,000
22.0	Construct concrete dams at edge of cross cuts to stope	22	EA	$150	$3,300
	Improve Access to Mine				
23.0	Russell Adit 1st cave-in excavation	20,000	CY	$5	$100,000
24.0	Install protective cover over portal repair	4,000	CY	$5	$20,000
25.0	Russell adit 1st cave-in sidewall and roof concrete panels	200	LF	$600	$120,000
26.0	Repair Russell Adit 2nd cave-in by opening and re-supporting	200	LF	$1,000	$200,000
27.0	Install new supports where required in adits and laterals	200	LF	$200	$40,000
28.0	Install matt lining and rock bolts where needed	200	LF	$350	$70,000
29.0	Install lighting in Stope	1	LS	$25,000	$25,000
30.0	Install lighting at stope dump areas and turn arounds	1	LS	$10,000	$10,000
31.0	Construct improved turn around access at portal dump entrances	7	EA	$30,000	$210,000
32.0	Provide fan and air circulation system	1	LS	$20,000	$20,000
33.0	Construct single air door at Asher Drift	1	EA	$1,000	$1,000
34.0	Construct single air door at East Reed Drift	1	EA	$1,000	$1,000
35.0	Construct double air doors at Russell Portal Drift	1	EA	$4,000	$4,000
	Reed Landing Sludge Holding Area				
36.0	Construct sludge holding basin at Reed Landing	1	LS	$20,000	$20,000

Bunker Hill
Acid Mine Drainage
Disposal of Dewatered Sludge in Hanna Stope
Order of Magnitude Cost Opinion

DATE: 27-Mar-00
PROJECT NO.: 148562.02.01
ESTIMATE BY: M Jackson

	DESCRIPTION	QTY	UNIT	TOTAL UNIT COST	TOTAL COST
	SUBTOTAL				$3,116,400
	MISC ALLOWANCE	10%			$311,640
	SUBTOTAL				$3,428,040
	CONTINGENCY	30%			$1,028,412
	SUBTOTAL				$4,456,452
	MOBILIZATION	15%			$668,468
	CONSTRUCTION TOTAL				$5,124,920
	SALES TAX ON MATERIALS	5.0%			$0
	ENGINEERING AND SUPPORT	20%			$1,024,984
	CONSTRUCTION MANAGEMENT	8%			$409,994
	CAPITAL TOTAL (ROUNDED)				$6,560,000
	ANNUAL O&M COST			$392,000	
	NPV OF ANNUAL O&M COSTS (30 YEARS @ 5% INTEREST)				$6,023,000
	TOTAL 30-YEAR PRESENT WORTH COST @ 5% INTEREST				$12,583,000

NOTES:

Misc Allowance markup is to include items known to exist but cannot be quantified at this time.
Contingency is for scope changes that are presently unforeseen.
Mobilization includes bonds, insurance, temporary facilities, health & safety, demobilization, etc.

NOTE: The above cost opinion is in August 1999 dollars and does not include escalation.
The order of magnitude cost opinion shown has been prepared for guidance in project evaluation at the time of preparation. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope, final schedule and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs must be carefully reviewed prior to making specific financial decisions or establishing final budgets.

O & M COST ESTIMATE DETAILS

Description	Qty	Unit	Unit Cost	Total Cost
Annual Costs				
Remove, Haul & Dispose in Hanna Stope	6,800	CY	$24	$163,200
Decanting of water from stope annually	1	LS	$25,000	$25,000
Testing and monitoring of water flows and water quality	300	CREW-HR	$60	$18,000
Maintenance and repair of access and facilities	1	LS	$120,000	$120,000
Maintenance of pumps and diversion system	1	LS	$10,000	$10,000
Power for ventilation and lighting	1	LS	$20,000	$20,000
Subtotal				$356,200
Contingency	10%			$35,620
Total Annual Cost				**$391,820**

NPV of Annual O&M Costs (30 years @ 5%) **$6,023,000**